

CONTRIBUTIONS  
FROM THE  
CUSHMAN FOUNDATION  
FOR  
FORAMINIFERAL RESEARCH

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# CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

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Hans E. Thalmann

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# 56. CRITICAL TAXONOMIC STUDY AND NOMENCLATURAL REVISION OF THE LITUOLIDAE BASED UPON THE PROTOTYPE OF THE FAMILY, LITUOLA NAUTILOIDEA LAMARCK, 1804

WOLF MAYNC  
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**ABSTRACT**—The genus *Lituola* LAMARCK, 1804, the type of the *Lituolidae*, reveals a non-labyrinthic interior structure and is placed in synonymy with *Haplophragmium* REUSS, 1860; the latter is, therefore, invalidated.

The forms of the *Lituola* lineage showing not a planispiral but a streptospiral irregular early coil are removed from *Lituola* and put into a new genus *Bulbophragmium* n. gen. Forms among the planispiral *Ammobaculites* trend which display the same streptospiral initial coiling are united in the new genus *Bulbobaaculites* n. gen.

As a consequence of the invalidation of *Haplophragmium* REUSS, the subfamily *Haplophragminiinae* is replaced by the *Haplophragmoidinae* n. subfam.; the subfamily *Lituoliniinae* auct. is restricted to include only simple forms that uncoil in the adult. The genera disclosing a reticulate hypodermis and labyrinthic interior are gathered in the subfamily *Spirocyklininae* MAYNC, 1949.

The following taxonomic changes were made:

*Cyclammina watersi* APPLIN and JORDAN, 1945, is referred to as *Lituola watersi* (APPLIN and JORDAN); *Cyclammina medwayensis* PARR, 1935, to *Haplophragmoides medwayensis* (PARR); *Haplophragmium taylorensis* CUSHMAN and WATERS, 1929, to *Lituola spinifera* n. sp.; *Lituola rugosa* d'ORBIGNY, 1850 (1847 MS) to *Pseudocyclammina rugosa* (d'ORBIGNY); *Ammobaculites coprolithiformis* (SCHWAGER) var. *sequana* MOHLER, 1938, to *Pseudocyclammina ammobaculitiformis* n. sp.; *Lituola siemiradzkii* CUSHMAN and GLAZEWSKI, 1949, to *Pseudocyclammina siemiradzkii* (CUSHMAN and GLAZEWSKI); *Pseudocyclammina rogalai* CUSHMAN and GLAZEWSKI, 1949 to *Lituola rogalai* (CUSHMAN and GLAZEWSKI).

The Cretaceous form *Cribrostomoides trinitatis* CUSHMAN and JARVIS is a true representative of the genus *Cribrostomoides* CUSHMAN and may not be classified under the genus *Barkerina*.

The genus-status of *Buccierenata*, *Cribrospirella*, and *Daxia* is hardly warranted; they should be lowered to subgeneric rank.

The genera *Amoastuta*, *Barkerina*, and *Haurania*, as well as the specialized groups of the *Endothyrinae*, *Loftusiinae*, and *Orbitolinidae*, are removed from the *Lituolidae*.

A key to the genera of the *Lituolidae* is proposed.

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For the various courtesies extended by many colleagues all over the world I feel deeply indebted. It is, in fact, almost impossible to acknowledge the assistance rendered by them in many respects. This unflinching cooperation proved indispensable for the kind of research work done which obviously had to be founded on as broad a base as possible. The merits that this paper may hold are, accordingly, an expression of this close cooperation.

The writer is under deep obligation to all who contributed in any respect to the progress of his studies. In particular he wishes to express sincere appreciation

to PIERRE MARIE, Paris, who donated numerous topotype specimens of LAMARCK's classical *Lituola nautiloidea*, the fundamental Lituolid form and genotype of *Lituola*. Ample material of *Lituola difformis* LAMARCK (*Cribrospirella* MARIE, 1941) was, moreover, put at his disposal.

Colleagues to whom the writer feels greatly obligated for having sent valuable Lituolid material are E. R. APPLIN, J. G. BURSCH, J. CUVILLIER, DON L. FRIZZELL, T. F. GRIMSDALE, H. GUNTER, SH. HANZAWA, J. HOFKER, F. G. KEYZER, G. A. DE NEVE, M. REICHEL, H. H. RENZ-RENZ, J. H. VAN VOORTHUYSEN, J. A. WATERS, and R. WEYNSCHENK.

The Museum of Natural History in Basle kindly loaned some topotype specimens of different species of *Pseudocyclammina* from the Swiss Jura Mountains which is gratefully acknowledged.

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The excellent microphotographs of the attached plates are due to the care and experience of A. SOMMER, Geological Institute of the University of Bern, Switzerland, to whom the writer is greatly indebted.

## INTRODUCTION

The systematic studies on the morphology and taxonomy of the *Lituolidae* presented here have revealed with increasing clarity that the nomenclature of many lituolid genera is actually in a state of great confusion.

There has been much disagreement regarding the various lituolid forms which time and again have been misinterpreted. There is even a strong controversy with respect to the interior structure of the genotype of the genus *Lituola* LAMARCK, 1804, *Lituola nautiloidea* LAMARCK. It is, therefore, not surprising that no satisfactory logical terminology has been devised so far and that a perplexity exists in the taxonomic hierarchy of this group of foraminifera which, in fact, is considered nowadays as a kind of a comprehensive "catch-all"-family.

Such obvious shortcomings are due to several factors. First of all it has to be emphasised that the genus *Lituola* LAMARCK, 1804, was inadequately figured by its author. The two species recognized by LAMARCK, viz. *Lituolites*<sup>1</sup> *nautiloidea* and *Lituolites*<sup>1</sup>

1 The fossil representatives of his genus *Lituola* were designated by LAMARCK as *Lituolites*.



*difformis*, were illustrated in rather schematic way only (LAMARCK, 1804, Pl. XIV., figs. 12 and 13 a-b). Even LAMARCK's figure 13b, showing a section of *Lituola difformis*, actually gives very little clue as to the inner structure and might rather depict some species of *Ammobaculites*, for instance.

It is remarkable, indeed, that up to the present day the genotype of *Lituola* has never been reproduced at all in a conclusive figure which is *de facto* the main source of the ambiguity and disagreement as to a sharply-defined classification of the *Lituolidae*. The illustrations of *Lituola nautiloidea* LAMARCK hitherto published are either schematized (D'ORBIGNY, 1840, Pl. II, figs. 28-31) or mere sketches (CUSHMAN, 1927c, Pl. 28, figs. 8-9; MARIE, 1941, Pl. II, figs. 13a-b, 14a-b; COLOM, 1946, Pl. XVIII, figs. 1-2), showing only the general outline of the test and the cribrate aperture. Some other figures of "*Lituola*" or "*Lituola nautiloidea*" actually represent different genera, not *Lituola* LAMARCK (HENSON, 1948, Pl. X, fig. 1; Pl. XIII, figs. 8, 18-19; CUSHMAN and GLAZEWSKI, 1949, Pl. I, figs. 4-10). A typical specimen of *Lituola nautiloidea* LAMARCK, identified as *Haplophragmium grande* (REUSS), however, is figured by A. FRANKE (FRANKE, 1928, Pl. XV, figs. 19a-b). To the best of the writer's knowledge, there does not exist one single figure (except for LAMARCK's fig. 13b, see above) disclosing the internal structure of the genus *Lituola* LAMARCK which is one of the really essential features in comparative morphology, taxonomy, and paleozoological nomenclature. Neither the surface features nor the character of the aperture alone can ever have a fundamental bearing on the classification of the Arenacea. Especially the external morphological characters generally do not reflect true relationships; they are very often unreliable for taxonomic purposes. Classifications based on external criteria have, therefore, very often led to serious errors. The genus *Daxia* CUVILLIER and SZAKALL, 1949, for instance, was characterized by its authors as being closely related to *Choffatella* SCHLUMBERGER (CUVILLIER and SZAKALL, 1949, p. 8). As revealed by thin-sections, however, this similarity of the genera in question is merely superficial. The interior structure of *Daxia* is by no means *choffatelloid* (see Pl. 9, fig. 3; and Pl. 11, fig. 4). It is an offspring of another lituolid radical (Haplophragmoidinae) lacking a reticulate hypodermis, regularly pierced septa, labyrinthic interior, etc. (see MAYNC, 1949, p. 535). Most probably, *Daxia* represents only a multichambered species of the genus *Haplophragmoides* CUSHMAN (see p. 47). Another form which has been misinterpreted because of its external appearance is "*Cyclammina*" *watersi* APPLIN and JORDAN, 1945, topotype material of which was kindly put at the writer's disposal by the Florida Geological Survey. The surface characters of this supposed *Cyclammina* actually recall similar features of the true *Cyclammina*. The inner structure, however, discloses

beyond any doubt that "*Cyclammina*" *watersi* is not related at all with the genus *Cyclammina* BRADY, 1876: The calcareous-chalky test, the regular strongly curved simple septa, the absolutely non-labyrinthic interior, the cribrate aperture, and the tendency to uncoil indicated in some specimens, prove that "*Cyclammina*" *watersi* APPLIN and JORDAN cannot be ascribed to *Cyclammina* but should be allocated to the genus *Lituola* LAMARCK, 1804 (see Pl. 12, fig. 11). Another "*Cyclammina*," viz. *C. medwayensis* PARR, 1935, cannot be distinguished externally from *Cyclammina*; the sectioned specimen figured by W. J. PARR (1935, text fig. 1), however, does not reveal a labyrinthic interior but merely thick agglutinated walls without any spongy cancellated structure. As the aperture is said to be a curved slit at the base of the last-formed chamber, this form should, therefore, be referred to the *Haplophragmoides* group. *Lituola rugosa* D'ORBIGNY is externally hardly distinguishable from any other species of the *Lituola-Haplophragmium* group. The presence of a labyrinthic wall structure (see Pl. 12, figs. 8-10), however, makes it imperative to refer this form to the genus *Pseudocyclammina* YABE and HANZAWA, 1926, and to list it as *Pseudocyclammina rugosa* (D'ORBIGNY).

These few examples sufficiently show that generic determinations should not be based on external characters alone.

The lack of usable illustrations of the genus *Lituola* LAMARCK has proved to be a serious handicap to students of lituolid foraminifera. There is, however, another omission to which the misinterpretation of this genus is largely due: None of the later workers on the *Lituolidae*, excepting P. MARIE, has apparently gone back to the original description of LAMARCK; instead of it the views of earlier authors were uncritically repeated. The only way out of the taxonomic dilemma concerning the *Lituolidae* is to eradicate obvious misconceptions and unbiasedly to go back to the original sources in order to clear up systematically the heterogeneous group of the *Lituolidae*.

It is an irreparable loss to the geological science that LAMARCK's large collection of fossils from the Basin of Paris, among which the type specimens of *Lituola nautiloidea* LAMARCK and *Lituola difformis* LAMARCK from the classical locality of Meudon, near Paris, was destroyed during the Second World War in Caen (collection DEFRANCE).

The sketches by both LAMARCK (1804) and J. A. CUSHMAN (1927) of specimens of *Lituola nautiloidea* from LAMARCK's original type slide are too poor for taxonomic purposes; the same must be said of the inadequately figured topotype specimens reproduced by P. MARIE in his exhaustive memoir (MARIE, 1941, Pl. II, figs. 13-14).

On the writer's request P. MARIE has visited the outcrops of Meudon and systematically sampled the exposed section in order to collect the topotypes of



*Lituola nautiloidea* LAMARCK, 1804, on which this paper is based. The writer feels exceedingly grateful and obliged for the cooperation of P. MARIE in this respect through whose courtesy ample topotype material for the present study was obtained. On account of the scarcity of this invaluable topotype material painstaking efforts were made to give genuine and instructive illustrations of LAMARCK's genus *Lituola*, in order to avoid future errors and misidentifications.

The available specimens, a few of which are here-with figured, are completely identical with LAMARCK's forms in the original collection DEFRANCE studied first-hand by P. MARIE before the war (personal communication of P. MARIE).

The topotype specimens of *Lituola nautiloidea* LAMARCK here studied come from the classical chalk exposures of Meudon, south of Paris, assigned to the zone of *Belemnitella mucronata* (SCHLOTHEIM) of the Upper Senonian (Campanian stage). According to P. MARIE the specimens were collected from his zones Em 3-4, near the base of the Meudon Cretaceous (see MARIE, 1941, pp. 263-264).

Other individuals of *Lituola nautiloidea* LAMARCK, put at the writer's disposal by P. MARIE, were collected at La Fontaine-aux-Bois, Department of Seine et Marne, about 90 Kms southeast of Paris. P. MARIE correlates this outcrop with his zone Em 3 of Meudon (MARIE, 1941, p. 264). At both localities *Lituola nautiloidea* LAMARCK is associated with *Lituola difformis* LAMARCK.

According to MARIE's zonation, *Lituola nautiloidea* is confined to the horizons Em 1 to Em 4 and *Lituola difformis* to Em 2 - Em 5 of the *Mucronata* zone. None of these species is represented in zone Eq [zone of *Gonioteuthis quadrata* (BLAINVILLE)].

*Lituola nautiloidea* LAMARCK is also recorded from the Upper Cretaceous of northern and central Germany, although some of the identifications may be doubtful. The specimen of *Lituola nautiloidea*, for instance, figured by A. FRANKE (FRANKE, 1928, Pl. XV, fig. 20) should not have been referred to *Lituola nautiloidea* LAMARCK but to *Haplophragmium grande* REUSS (1854, Pl. XXV, figs. 14a-b) or *Haplophragmium irregulare* (ROEMER) REUSS (1860, Pl. X, figs. 9a-b) both of which are obviously conspecific. The specimen of *Haplophragmium grande* REUSS, figured by FRANKE (loc. cit., Pl. XV, figs. 19a-b), on the other hand, is definitely identical with *Lituola nautiloidea* LAMARCK. Many other examples revealing the state of general taxonomic confusion within this lituolid group could be given which, however, is not within the scope of the present paper.

The mere fact that many forms of the morphological unit *Lituola-Haplophragmium* were allocated in the literature to widely different genera, such as *Ammobaculites*, *Ataxophragmium*, *Cribrospira*, *Cribrostomoides*, *Cyclammina*, *Haplophragmoides*, *Nonionina*,

*Orbignyna*, *Placopsilina*, *Spirolina*, etc., clearly reflects the weakness of the existing classification and the urgent need for revision and clarification.

# CRITICAL TAXONOMIC REVISION OF LITUOLA LAMARCK, 1804 AND HAPLOPHRAGMIUM REUSS, 1860

## 1) *Lituola* LAMARCK, 1804

In his classical paper on the fossils from near Paris, in 1804, LAMARCK described and figured two species of his new genus *Lituola/Lituolites* (LAMARCK, 1804, p. 242; Pl. XIV, figs. 12 and 13). The following diagnosis of the genus *Lituola* was given:

"Testa univalvis, multilocularis, partim in spiram convoluta; anfractu ultimo ad extremum recto. Loculi irregulares. Septa transversa simplicia: ultimo multiforo" (LAMARCK, 1804, p. 242).

LAMARCK's definition thus contains the statement that the genus *Lituola* is characterized by irregular chambers and by simple septa. As is obvious from the text in LAMARCK's work (p. 243), however, the term "irregular chambers" is used to denote the varying size and arrangement of the loculi and certainly not to designate anything like secondary ingrowth from the wall or partial filling up of the chambers. LAMARCK was evidently aware that *Lituola* has a simple inner structure although it may display some irregularities as to the size and disposition of the chambers. None of the numerous thin-sections of either *Lituola nautiloidea* or *Lituola difformis* prepared and studied by the writer, however, showed such an irregular arrangement of chambers as depicted by LAMARCK (1804, Pl. XIV, fig. 13b).

Contrary to LAMARCK's original definition, ALCIDE D'ORBIGNY stated that the genus *Lituola* has labyrinthic chambers.<sup>2</sup> The same internal structure was ascribed to the species *Lituola nautiloidea* LAMARCK.<sup>3</sup> As explained by P. MARIE (1941, p. 256), this erroneous statement as to a labyrinthic structure of this genus has its origin in the fact that D'ORBIGNY had thin-sectioned a specimen of *Lituola* and studied it without having washed the slide, on account of which he observed the chambers to be filled up partially with ground chalk (impression of vesicular material filling partially the chambers).

It is of interest to note that D'ORBIGNY considered LAMARCK's two species of *Lituola*, namely *L. nautiloidea* and *L. difformis*, to be merely varieties of one single species (D'ORBIGNY, 1840, p. 4, footnote 2). Sharing this opinion, the writer opposes the contrary view of P. MARIE who even erected a new genus *Cribrospirella* MARIE, 1941, with *Lituola difformis* LAMARCK as genotype (MARIE, 1941, p. 28).

In his monograph on the Cretaceous foraminifera

2 " . . . son intérieur est plein et divisé irrégulièrement" (D'ORBIGNY, 1840, p. 29).

3 " . . . l'intérieur des lozes, au lieu d'être vide, comme dans les Spirolines, paraît être criblé ou poreux" (D'ORBIGNY, 1840, p. 29).



from Westfalen, Germany, A. E. REUSS established the new genus *Haplophragmium* (REUSS, 1860, p. 217). *Spirolina* ROEMER, 1841 (non LAMARCK) and *Spirolina aequalis* ROEMER, 1841, were subsequently designated as genotype and type species (CUSHMAN, 1920, p. 67). The new genus *Haplophragmium*, however, as stated by REUSS differs from the isomorphic genus *Spirolina* LAMARCK, 1804 (non ROEMER), in having an arenaceous test. Both *Spirolina* LAMARCK and *Haplophragmium* REUSS display simple chambers. According to REUSS (*loc. cit.*), the genus *Lituola* LAMARCK, 1804, on the other hand, differs from *Haplophragmium* in having a labyrinthic interior structure.<sup>4</sup> The original definition of *Lituola* LAMARCK, 1804, had thus become adulterated and mutilated. This misinterpretation has since caused increased confusion to all subsequent workers and led to the present-day's taxonomic chaos of the *Lituolidae*.

In 1862, REUSS lowered the genus *Lituola* LAMARCK to subgeneric rank (*Lituola* s. str.) and retained the concept of its irregular labyrinthic structure (REUSS, 1862, p. 381.<sup>5</sup>)

From this time onward up to the present day the wrong concept that *Lituola* LAMARCK possesses a labyrinthic interior structure has crept into the micropaleontological literature.

In his fundamental work on the foraminifera dredged by H.M.S. CHALLENGER, for instance, H. B. BRADY dealt at some length with the *Lituolidae*, especially with the genus *Cyclammina* (BRADY, 1884). Both arenaceous and calcareous genera were included in the family *Lituolidae*, and the former grouped in the new subfamily *Lituolinae* BRADY (BRADY, 1884, p. 65). Among the *Lituolinae*, comprising the arenaceous genera, BRADY separated the simple forms (*Reophax*, *Haplophragmium*, etc.) from those exhibiting labyrinthic chambers, such as the genera *Haplostiche* REUSS, *Lituola* LAMARCK, (in *loc. cit.*, p. 65). BRADY thus supported also the concept that *Lituola* LAMARCK is characterized by a labyrinthic interior structure. The only difference between the diagnosis given by BRADY for *Haplophragmium* REUSS and *Lituola* LAMARCK is actually the labyrinthic interior of the latter genus<sup>6</sup> which, however, is *de facto* not labyrinthic at all.

Prior to BRADY, the coarsely agglutinated Arenacea had been considered to be varieties of one single species, viz. *Lituola nautiloidea* LAMARCK. BRADY, however, favored the view that these forms should be regarded as different genera and be included in the new subfamily *Lituolinae*, rather than taken for varieties

or subgenera of *Lituola* LAMARCK (BRADY, 1884, p. 285).

In his monograph on the foraminifera of the Atlantic Ocean, J. A. CUSHMAN designated *Lituola nautiloidea* LAMARCK as genotype of the genus *Lituola* LAMARCK (CUSHMAN, 1920, p. 69). The following diagnosis was given for *Lituola* LAMARCK:

"Test crozier-shaped, the early portion planospiral, the later portion uncoiled and straight, test arenaceous, the chambers labyrinthic with radial vertical partitions and secondary septae; aperture typically of several pores" (in *loc. cit.*, p. 69).

In 1927, CUSHMAN published the following diagnosis of *Lituola* LAMARCK in his outline of a re-classification of the Foraminifera (CUSHMAN, 1927, p. 21):

"Test with the young close-coiled, later adult portion uncoiled and straight; chambers labyrinthic with radial vertical partitions and secondary septae; aperture typically of several pores."

In another paper published in 1927, CUSHMAN made the following remarks concerning *Lituola* LAMARCK and its two species:

"*Lituola* LAMARCK, 1804, has two species *L. nautiloidea* and *L. difformis* LAMARCK of which *L. nautiloidea* should be designated as the genotype. It is a test close coiled and involute in the young, uncoiling in the adult, and having several openings in the terminal apertural face. From the description given by LAMARCK, the wall may be inferred to be arenaceous and the interior labyrinthic. This agrees well with the restricted use now being made of *Lituola*" (CUSHMAN, 1927c, p. 125).

In opposition to these characteristics is the diagnosis of *Lituola* LAMARCK given by CUSHMAN in his note on the collection DEFRANCE (CUSHMAN, 1927c, p. 142-143), where he redescribed LAMARCK's type specimens as follows:

"There are 14 specimens on the slide, one very large, the holotype, figured by LAMARCK. The early portion is close coiled and the last three chambers uncoil. The aperture is multiple and terminal in the adult and even in the later portion of the coiled adult the apertures are multiple as shown in the sketches (pl. 28, figs. 8, 9). "As shown by the excellent sections on the slide the aperture in the young is simple, at the base of the apertural face as in *Haplophragmoides*. The test is made of white agglutinated material with a fairly smooth surface, easily eroded and showing the rough character of the structure of the wall. The interior is not labyrinthic and it is probable that *Lituola* will include those Cretaceous species which were referred to *Haplophragmium* REUSS.

"*Lituola difformis* also from Meudon has 11 specimens on its type slide, some of which are sections. It is very globular, with 5 or 6 chambers in the coil, the last of which starts to uncoil. The surface is also smoother than in *L. nautiloidea*" (CUSHMAN, 1927c, p. 142-143).

CUSHMAN thus clearly points out in this article that *Lituola nautiloidea* of LAMARCK's type slide lacks a labyrinthic interior structure. Notwithstanding this correct statement, the false idea of *Lituola* having a labyrinthic interior was not given up at all. In his remarkable standard-work "Foraminifera, their classification and economic use," published in 1928 (and later editions in 1933, 1940, and 1948), CUSHMAN still

4 "Bei *Lituola* werden dieselben (Kammerhöhlungen) durch zahlreiche sehr regellose und anastomosierende Scheidewände vielfach unterabgetheilt und erhalten ein zelliges Ansehen" (REUSS, 1860, p. 217).

5 "Kammerhöhle durch regellos anastomosierende secundäre Septa unterabgetheilt, zellig" (REUSS, 1862, p. 381).

6 "The genus *Haplophragmium*, as instituted by REUSS, is distinguished from *Lituola* (proper) by its non-labyrinthic chambers" (BRADY, 1884, p. 300).



advocates the concept that LAMARCK's genus *Lituola* is characterized by a labyrinthic interior structure. This misconception, which beyond a doubt added to the general nomenclatural confusion, has, unfortunately, been uncritically accepted by many authors and found entrance in countless systematic papers and manuals, as f. i. in K. von ZITTEL's "Grundzüge der Paläontologie," 1924; J. J. GALLOWAY's "Manual of Foraminifera," 1933; "Index Fossils of North America" by H. W. SHIMER and R. R. SHROCK, 1944; G. COLOM's "Introducción al estudio de los Microforaminíferos fosiles," 1946; M. F. GLAESSNER's "Principles of Micropaleontology," 1947, etc. F. R. S. HENSON even reports the genus *Lituola* to possess a subepidermal reticulate layer with both transverse and parallel partitions (HENSON, 1948, p. 8-10). This statement gives clear evidence that the genus *Lituola* LAMARCK is thoroughly misinterpreted and is in fact confounded with *Pseudocyclammina* YABE and HANZAWA, 1926. There is, as a matter of fact, no diagnostic differentiation between *Lituola* HENSON, 1948 (non LAMARCK, 1804) and *Pseudocyclammina* YABE and HANZAWA, 1926, a point which has been brought forward by the writer in a recent publication (MAYNC, 1949, p. 538). HENSON himself must have felt somewhat vague about this nomenclatural problem as is apparent in his statement that "the generic distinction between *Lituola* and *Pseudocyclammina* is by no means clear, and a review of all the species attributed to each genus is desirable" (HENSON, 1948, p. 10), and "its (*Lituola*) distinction from the latter (*Pseudocyclammina*) is not altogether clear" (*ibid.*, p. 22).

The very same mistake of confounding *Lituola* LAMARCK and *Pseudocyclammina* YABE and HANZAWA was made by J. A. CUSHMAN and K. GLAZEWSKI who recorded new species of these genera from the Upper Jurassic of Poland (CUSHMAN and GLAZEWSKI, 1949). Thanks to the courtesy of CAMERON D. OVEY from the British Museum, London, the writer could examine a few topotype specimens of some of these Polish forms, i. e. *Pseudocyclammina rogalai* CUSHMAN and GLAZEWSKI, *Lituola siemiradzskii* CUSHMAN and GLAZEWSKI, and *Lituola compressa* CUSHMAN and GLAZEWSKI. The available specimen of each form was thin-sectioned by the writer. The specimen P. 39266, labeled as *Pseudocyclammina rogalai* CUSHMAN and GLAZEWSKI, shows neither a reticulate hypodermis nor a labyrinthic wall structure, but merely very thick homogeneous, finely arenaceous walls and septa, with irregularly outlined lumina. On account of its simple interior structure, the examined specimen of *Pseudocyclammina rogalai* CUSHMAN and GLAZEWSKI should be referred to the genus *Lituola* LAMARCK.

*Lituola siemiradzskii* CUSHMAN and GLAZEWSKI, on the other hand, of which one topotype specimen (P. 39268) could be thin-sectioned, shows a thin reticulate near-surface layer and a distinct labyrinthic wall

structure with ramifying passages. There is, accordingly, no doubt that "*Lituola*" *siemiradzskii* has wrongly been assigned to the genus *Lituola* LAMARCK; it should in future be listed as *Pseudocyclammina siemiradzskii* (CUSHMAN and GLAZEWSKI).

It is the merit of P. MARIE to have emphasised the fact that the genus *Lituola* LAMARCK (based on *Lituola nautiloidea* LAMARCK) discloses a non-labyrinthic inner structure (MARIE, 1941, p. 20-21; 27-28; 256-257). According to MARIE's emended diagnosis, only arenaceous thick-walled forms showing a regular planispiral initial coil, simple (non-labyrinthic) chambers, and a cribrate aperture are referred to *Lituola* LAMARCK. Externally, *Lituola* is stated to resemble *Cyclammina* and *Pseudocyclammina* which, however, have a labyrinthic interior. From *Haplophragmium* REUSS *et auct.* (based on *Spirolina aequalis* ROEMER!), *Lituola* differs in having a regular early spire, not an irregular, clew-like ("*pelotonnée*") one. All the irregular *Lituola*-like forms with labyrinthic chambers are grouped by MARIE in a new genus *Pseudolituola* (MARIE, 1941, p. 21, 256) which, however, is a *nomen nudum* as no genotype, figure, or description is given (MAYNC, 1949, p. 536). In view of their complexity, the labyrinthic *Lituola*-like forms cannot be placed into one single genus and, therefore, have been allocated to the subfamily *Spirocyclininae* MAYNC, 1949.

The concept that *Lituola nautiloidea* LAMARCK is internally simple is fully endorsed by the writer's studies as the thin-sections figured (Pl. 9, figs. 4, 5, 7, 8) prove beyond a doubt: *The interior structure of Lituola nautiloidea* LAMARCK is non-labyrinthic and there is not the slightest trace of an alveolar hypodermis. The aperture which — in combination with other basic morphological criteria — is of great importance for systematic purposes, consists of several pores on the apertural face (cribrate). (See Pl. 9, fig. 2).

## 2) *Haplophragmium* REUSS, 1860

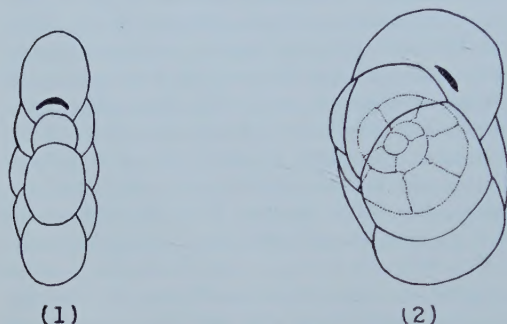
On account of the fact that REUSS omitted to indicate a genotype for his new genus *Haplophragmium* (1860), *Spirolina aequalis* ROEMER, 1841, was subsequently designated as genotype (CUSHMAN, 1920, p. 67). Contrary to most of the forms referred in the course of time to *Haplophragmium* REUSS, *Spirolina aequalis* ROEMER, 1841 (Pl. 15, fig. 27) does not display a regular planispiral initial coil, nor a trochospiral one, but its early spire is irregularly coiled in varying planes, like a clew of yarn ("*pelotonnée*"; *streptospiral*<sup>7</sup>).

Unfortunately, however, many forms described and refigured in the literature, subsequent to F. A. ROEMER and A. E. REUSS, as *Haplophragmium aequale* (ROEMER) do not show this irregular streptospiral coil of the original *Spirolina aequalis* ROEMER, 1841, and *Haplophragmium aequale* (ROEMER) REUSS, 1860

<sup>7</sup> *Streptos* (Gr.) = curved, twisted.



(REUSS, 1860, Pl. XI, figs. 2a-3a; see Pl. 10, fig. 7-10 of the present paper); their attribution to *Haplophragmium* (olim *Spirolina*) *aequale* (ROEMER) was, therefore, not justified (see for instance CHAPMAN, 1892, Pl. VI, figs. 1-3; CHAPMAN, 1926; FRANKE, 1928, Pl. XV, fig. 15; GERMERAAD, 1946, Pl. VI, fig. 17; TEN DAM, 1946, Pl. 87, figs. 3-4, etc.).



Text Fig. A). Types of coiling:  
(1) Planispiral (coiled in one single plane)  
(2) Streptospiral (coiled in varying planes)  
(After H. HÖGLUND, 1947).

As the mode of the early spire is regarded by the writer as a fundamental taxonomic feature, *Spirolina aequalis* ROEMER should, accordingly, not be grouped together with forms that develop a single-planned spire. No type has been given by A. E. REUSS, unfortunately, but in his important work (1860, p. 217) *Haplophragmium* is clearly stated to be the arenaceous pendant to the genus *Spirolina* LAMARCK, 1804 (non ROEMER, 1841) possessing a calcareous, imperforate-porcellaneous test which definitely shows a planispiral initial coil.<sup>8</sup> On this account it is imperative that, according to REUSS' original concept of his new genus, only isomorphs of *Spirolina* LAMARCK, 1804 (non ROEMER!), should be included in *Haplophragmium*. In our opinion, the designation of *Spirolina aequalis* ROEMER, 1841, as genotype of *Haplophragmium* REUSS, 1860, by CUSHMAN was, therefore, a mistake because the original conception of the concerned genus has thus become mutilated and been given quite a different meaning. It is, as a matter of fact, not understandable why *Spirolina aequalis* ROEMER was selected as genotype of *Haplophragmium* REUSS, 1860, as F. A. ROEMER's illustrations (ROEMER, 1841, Pl. 15, fig. 27) distinctly depict a specimen displaying an irregular non-planispiral early coil. In his diagnosis of *Haplophragmium* REUSS, however, CUSHMAN clearly states the following:

"Test in the early portion close coiled, **planospiral**, (see ref. 9) later becoming uncoiled and straight" (CUSHMAN, 1920, p. 67).

and

8 . . . "Coquilles multiloculaires, qui commencent d'abord en faisant un ou deux tours en spirale sur le même plan, et qui ensuite s'allongent en ligne droite" . . . (LAMARCK, 1804, p. 244).

"the genus as used by REUSS has been variously applied until at one time used for all the coiled, trochoid, or irregularly coiled tests with coarse, arenaceous walls. It is here used in its original sense (see ref. 9) as nearly as can be determined" (in loc. cit., p. 68).

In the writer's opinion, the original description in REUSS' publication on the genus *Haplophragmium* (1860) dictates that *Haplophragmium*, stated to be an isomorph of *Spirolina* LAMARCK, 1804, only comprises planispirally coiled forms. The genotype, subsequently selected by CUSHMAN was, therefore, ill-chosen because it does not bear the characteristics set forward by REUSS; *Spirolina grandis* REUSS, 1854, for instance, should have been proposed as genotype of *Haplophragmium* REUSS, 1860, since the original figures 14a and 14b of this form (reproduced here on Pl. 10, figs. 11, 12) clearly show the planispiral coiling of the initial spire (REUSS, 1854, Pl. XXV, figs. 14a-b). Another suitable genotype would have been *Haplophragmium aequale* REUSS 1862 (REUSS, 1862, Pl. I, figs. 1-7).

As the original *Spirolina aequalis* ROEMER (in ROEMER, 1841, Pl. 15, fig. 27) clearly shows a simple aperture, its attribution to the *Lituola*-*Haplophragmium* group is anyway not admissible. It obviously belongs to the *Ammobaculites* group and is, on account of its irregularly twisted initial spire, referred to the new genus *Bulbobaculites* n. gen. (see p. 47).

As a consequence of the foregoing discussion, *Haplophragmium aequale* (ROEMER) REUSS (1860, Pl. XI, figs. 2a and 3a; reproduced on Pl. 10, figs. 7-10), and similar forms with a bulb-like initial spire coiled in different planes (streptospiral, not planispiral coil) are herewith removed from the *Haplophragmium*-*Lituola* group and are included in a new genus, *Bulbophragmium* n. gen.<sup>10</sup> with *Haplophragmium aequale* (ROEMER) REUSS, 1860 (Pl. XI, fig. 2a) as genotype.

*Haplophragmium aequale* (ROEMER) REUSS, 1860, has recently been suspected to be the microspheric (A-2) form of *Haplophragmium grande* (REUSS) (HOFKER, 1949, p. 6-7). In view of the great difference of the early coil of these forms, the former being an irregular clew-like spire in different planes, the latter showing a planispiral coil, the author disagrees with J. HOFKER in this respect.

The different mode of planispiral and streptospiral coiling as exhibited between *Haplophragmium* (olim) and *Bulbophragmium* is also manifested in other foraminiferal groups; the genus *Ammodiscus*, showing a regular spire in one single plane, bears the same relationship to the streptospirally coiled genera *Glomospira* and *Lituotuba* (type *lituiformis*); *Cribrostomoides* and *Recurvoides* are systematically separated because of the same principal difference in coiling; among the endothyroid-fusulinid group, the genera *Cribrospira*, *Plectogyra*, *Haplophragmella*, *Rauserella*,

9 By the writer.

10 **Bulbus** (Lat.) = bulb; name chosen because of the bulb-like aspect of the irregularly coiled early portion.



etc. show an asymmetric spire coiled in varying planes similar to the streptospirally coiled *Bulbophragmium*; *Haplophragmella*, moreover, differs from *Plectogyra* as *Bulbophragmium* from *Recurvoides* in showing an uncoiled adult portion and a cribrate aperture. In view of the complex fusulinid wall-structure of the above-mentioned genera, however, the writer decidedly objects to place them in the family of the *Lituolidae*.

Adhering to REUSS' definition (REUSS, 1860, p. 217) that *Haplophragmium* is isomorphic with *Spirolina* LAMARCK, 1804 (non ROEMER, 1841) and having seen that *Lituola* LAMARCK possesses a simple (non-labyrinthic) interior structure like *Haplophragmium* REUSS (see p. 46 of the present paper), the conclusion of a complete synonymy between *Lituola* LAMARCK, 1804, and *Haplophragmium* REUSS, 1860, is inevitable. Both forms disclose a similar general shape of their tests, a planispiral early coil and rectilinear adult stage, a cribrate aperture, and non-labyrinthic walls and septa. The congruity of both forms mentioned may be checked in any textbook on foraminifera, provided the fundamental correction as to the simple inner structure of *Lituola* LAMARCK is made. The only difference between *Lituola* LAMARCK and *Haplophragmium* REUSS lies in the texture (not structure) of the wall: In *Lituola*, the test generally consists of microgranular chalky material containing some scarce accessory foreign particles; in *Haplophragmium*, it is largely made up of agglutinated sand grains of varying size and amount, held together by a microgranular calcite cement. Both the ratio arenaceous particles/cement and the degree of coarseness of the added foreign material are very variable as they depend on the environmental conditions of the form in question. On this account, there naturally exists a great variability with regard to the texture, and all transitional stages between the essentially calcareous-detrital test of "*Lituola*," consisting almost exclusively of cement, and the coarsely arenaceous representatives of "*Haplophragmium*" auct. at the other end of the lineage may occur.

These gradual differences of texture, however, depending on exogenous ecological factors alone, can never be of fundamental significance and do in our opinion not warrant a splitting up into different genera. Who would ever dream of laying much weight, let alone of basing a natural classification, on the variations of the amount of agglutinated material in the test of *Orbitolina*, for instance?! The writer has observed every possible intergradation on specimens of *Choffatella decipiens* SCHLUMBERGER showing an essentially agglutinated, finely arenaceous test to others built up entirely of calcareous matter — and both extremes are not only congeneric but even conspecific forms! Any cut in the trend of transitional forms between *Lituola* and *Haplophragmium*, suggested, f. i. by P. MARIE (1941, p. 19-21), is bound to be arbitrary, artificial and, therefore, of no systematic and taxo-

nomic value, and the sharp delimitation of different genera or subgenera within this morphological unit would be frustrated. A study of the hitherto described species of *Lituola* and *Haplophragmium* convincingly shows the indefensibility of a classification along such lines. The difficulty and uncertainty as to the nomenclatural status of a great many forms of the lineage *Lituola*-*Haplophragmium* are revealed in almost any paper on lituolid foraminifera, forms having texturally a *Lituola*-like test being referred to *Haplophragmium* and others showing a coarsely arenaceous test to *Lituola*.

Neither can the extreme members of the gradational row of simple lituolid forms be separated and designated by different names as there will be absolutely no clear-cut criterion to determine the taxonomic position of the intermediate stages or forms. Any differentiation would be wholly subject to the individual judgment of each worker on this group of foraminifera, with the result that the uniformity of diagnosis would be futile and the confusion as to taxonomy as great as before.

In the light of the foregoing the conclusion is, consequently, reached that all the forms represented in the above-outlined morphological unit *Lituola*-*Haplophragmium* have to be gathered in one single genus. According to the rule of priority, the older of the two synonyma has to be retained, and *Lituola* LAMARCK, 1804, has thus preference over *Haplophragmium* REUSS, 1860.

It could be argued that *Haplophragmium* REUSS be degraded to subgeneric rank and applied to forms exhibiting a chiefly arenaceous wall texture while a subgenus *Lituola* s. str. be used for forms possessing an essentially calcareous test. Such a procedure, however, would again meet with the difficulties outlined above, i. e. the two subgenera would be arbitrarily and inconsistently delimited according to the individual opinion of each student.

*Haplophragmium* REUSS had actually been considered by some authors to be a subgenus of *Lituola* LAMARCK (REUSS, 1862, BÜTSCHLI, 1880, ZITTEL, 1880, JONES, 1884, etc.). A close relationship between *Lituola* LAMARCK and *Haplophragmium* REUSS was also suspected by A. GOËS as is evident from his statement on *Haplophragmium lituolinoideum* GOËS, 1896: "It would perhaps be consistent with a more philosophic view to range this form as a simplified variety of *Lituola nautiloidea* (LMCK.) [*L. nautiloides* d'ORB., 1840, Mém. Soc. Géol. Fr. (1), IV, p. 29, Pl. II, Figs. 28-31], from which it differs only in smaller size and undivided chambers" (GOËS, 1896, p. 32).

According to A. FRANKE, *Lituola nautiloidea* LAMARCK d'ORBIGNY, 1840, is synonymous with *Haplophragmium grande* (REUSS) (FRANKE, 1927). As is obvious from P. MARIE's synonymy list (MARIE, 1941, p. 27-28), *Lituola nautiloidea* LAMARCK had been



placed in synonymy with several forms of the genus *Haplophragmium* REUSS, 1860, such as *Spirolina irregularis* ROEMER, 1841, *Spirolina inaequalis* REUSS, 1846, *Haplophragmium grande* BEISSEL, 1891, EGGER, 1899, FRANKE, 1928, *et al.*, and *Haplophragmium irregularis* EGGER, 1899.

In view of their irregularly coiled initial spire, however, several forms described as *Haplophragmium irregulare auct.* seem rather referable to *Bulbophragmium n. gen.*, but an extensive study of topotype material is absolutely necessary to reach a decision.

The Senonian *Spirolina lagenalis* ROEMER, 1841, on the other hand, might possibly be conspecific or at least closely related to LAMARCK's *Lituola difformis* or *L. nautiloidea*.

Because of the synonymy of *Lituola* LAMARCK, 1804, and *Haplophragmium* REUSS, 1860, some species of either form become now homonyms, e. g. *Lituola taylorensis* CUSHMAN and WATERS, 1929, and *Haplophragmium taylorensis* CUSHMAN and WATERS, 1929. The new name *Lituola spinifera n. sp.* is here proposed for *Haplophragmium taylorensis* CUSHMAN and WATERS, 1929, in consideration of the striking spur shown on the type figures (CUSHMAN and WATERS, 1929, Pl. 10, figs. 4a-b).

#### REMARKS ON THE CLASSIFICATION OF THE LITUOLIDAE

Modern trends in paleozoology rightly object to a specialization *ad extremum*, to an arbitrary splitting up of established wide-limited genera which is based on individual morphological, ecological, and sometimes even pathological differences of hardly any significance. The extreme and undue dissection and multiplication of genera, the liberality of introducing new names at random which — according to the International Rules of Zoological Nomenclature — can never be wiped out, have led to the present-day's taxonomic confusion. Instead of creating a profusion of new genera, it should be the aim of the taxonomist to emphasize structural-morphological similarities, to disclose degrees of affinities, and to group them to logical phylogenetical units. In foraminifera systematics, too, we should tend to unify rather than disperse. If merely the differences are stressed, the classification of many a group of foraminifera will in the long run be deranged and incomprehensible unless our ideas concerning the genus-conception be broadened. The minor and subtle morphological differences between some genera and subgenera should rather be expressed in different species. The present-day's sophisticated nomenclature of the Mesozoic Ammonoidea, for instance, is certainly discouraging enough to be strived after for a terminology of the foraminifera.

In consequence of the fact that the interior structure of *Lituola* LAMARCK is not labyrinthic (as was hitherto

generally assumed) and that the genera *Lituola* LAMARCK and *Haplophragmium* REUSS are shown to be synonyma, the whole classification of the *Lituolidae* had to be revised. Owing to its inner structure, *Lituola* can obviously not be upheld as the type genus of the subfamily *Lituolinae auctorum*, comprising only labyrinthic genera. In 1941, P. MARIE, therefore, proposed the new subfamily *Cyclammininae* to unite the forms displaying labyrinthic chambers (MARIE, 1941, p. 257); this term, however, has to be rejected as some genera showing a cellular-near-surface layer (of which *Cyclamina* is a typical example) were gathered in the family *Spirocyclinidae* MUNIER-CHALMAS, 1887 emend. BONTE, 1942 (see BONTE, 1942). Since these forms, on the other hand, are derived from a lituolid stock, the *Spirocyclinidae* were lowered to subfamily rank (*Spirocyclininae* MAYNC, 1949) by the author (MAYNC, 1949, p. 538).

While the *Spirocyclininae* thus include the lituolid offsprings endowed with an alveolar hypodermis and a labyrinthic interior, all the simply built genera are now separately grouped in two other subfamilies: The *Haplophragmoidinae nov. subfam.*, comprising all the non-labyrinthic forms that remain coiled in the adult, and the *Lituolinae s. str.* MAYNC, comprehending the non-labyrinthic genera which uncoil in later ontogenetic stages. The term *Lituolinae*, though in a restricted sense, has been maintained in view of its traditional use.

The type genera of the three lituolid subfamilies established by the author are *Haplophragmoides* CUSHMAN, 1910 (genotype: *Nonionina canariensis* D'ORBIGNY, 1839); *Lituola* LAMARCK, 1804 (genotype: *Lituola nautiloidea* LAMARCK, 1804); *Spirocyclina* MUNIER-CHALMAS, 1887 (genotype: *Spirocyclina choffati* MUNIER-CHALMAS, 1887).

The classification of the *Lituolidae* proposed in this paper differs in several respects from the older ones. First and foremost, the dogma of *Lituola* having a labyrinthic interior structure is abolished, a misconception which had been accepted by nearly all micro-paleontologists prior to P. MARIE. Since *Lituola* LAMARCK and *Haplophragmium* REUSS are shown to be synonyma and the latter genus is invalidated, it cannot be considered any more as type of the subfamily *Haplophragmiinae*; *Haplophragmoides* CUSHMAN is, on this account, picked as type of the new subfamily *Haplophragmoidinae* which is limited to include planispirally coiled simple tests in all stages. The non-labyrinthic forms uncoiling in the adult are referred to the subfamily *Lituolinae s. str.* Originally, the *Lituolinae* BRADY, 1884, included both simple and labyrinthic genera (BRADY, 1884, p. 65); in the subfamily *Lituolinae auctorum*, however, only the labyrinthic forms were hitherto assembled (GALLOWAY, 1933; CUSHMAN, 1948; COLOM, 1946, GLAESSNER, 1947, etc.). As *Lituola* LAMARCK is now definitely proved to belong to the non-labyrinthic genera, it cannot form the type of



a subfamily characterized by forms with a labyrinthic interior.

All the litiolid genera possessing a reticulate hypodermis and a labyrinthic interior structure have been grouped in the subfamily *Spirocyclininae* MAYNC, 1949.

BRADY's subfamilies *Loftusiinae* and *Endothyriinae* are specialized enough to be treated as separate families. The same may be said of the complex group of the *Orbitolinidae* and its forerunners. The early Jurassic genera *Orbitopsella* MUNIER-CHALMAS and *Orbitamina* BERTHELIN lack the reticulate hypodermis (see BONTE, 1942) and are, consequently, herewith removed from the *Spirocyclininae*. Another group of genera formerly included in the *Lituolidae* such as *Cyclolina* D'ORBIGNY (= *Peneroplis* MONTFORT) and *Cyclopsinella* GALLOWAY have been shown to belong to the *Peneroplidae* (HENSON, 1950). The genus *Dictyopsella* MUNIER-CHALMAS with its trochoid initial spire seems to belong to the *Valvulinella* stock (HENSON, 1947).

The new classification as outlined above sharply delimits the externally similar genera by reason of their different mode of coiling and/or their different interior structure. In our opinion, superficial similarities are of little value as a basis for a stable taxonomy of arenaceous foraminifera. A few examples of generic misidentifications based on surface characters of the test have already been given (see p. 36). Neither are textural affinities apt to serve a taxonomic purpose. P. MARIE, for instance, places *Lituola* LAMARCK (and his new genus *Criborespirella*) among the endothyroid genera only because of the similar texture of their tests (built up of predominantly calcareous-detrital material). By reason of its calcareous microgranular texture also the valvulinid genus *Orbignyna* HAGENOW is allocated by P. MARIE to the *Lituolidae* (MARIE, 1941).

The most reliable criterion of generic distinction is certainly the inner structure laid bare by thin-sections. A thorough internal study of *Lituola* LAMARCK, for instance, would have settled its taxonomic position decades ago. Statements such as "*Cyclammina* evolved into *Pseudocyclammina* by becoming slightly evolute, and that genus developed into *Lituola* by increasing the length of the evolute portion" . . . "*Choffatella* is little more than a compressed *Cyclammina*" (GALLOWAY, 1933, p. 193) would never have been made had thin-sections of those forms been studied.<sup>11</sup> *Cyclammina* and *Choffatella* do not only differ in their aperture as has been assumed (HENSON, 1948, p. 8) but show a different interior structure; *Alveolophragmium* would never have been placed among the non-labyrinthic litiolid genera (CUSHMAN, 1948, p. 102, 454) had its interior been examined; a thin-section of *Ammonoastuta* would have revealed that this genus lacks an early coiled portion and is, therefore, not a litiolid

foraminifer at all. More examples of misconceptions, caused by the omission of a study of the internal characteristics, could be quoted.

## CLASSIFICATION OF THE FAMILY

### LITUOLIDAE

(see key p. 52)

#### *Lituolidae* BRADY

Test free, multilocular; chambers arranged in a planispiral, rarely in a trochospiral or streptospiral coil; spire in adult stages often uncoiling or becoming reniform-annular; walls and septa arenaceous (with a varying amount of calcareous cement) or entirely calcareous (microgranular); interior simple or complex (labyrinthic); imperforate epidermal layer, sometimes underlain by a reticulate-alveolar hypodermis; aperture simple or multiple.

#### Subfamily I. *Haplophragmoidinae* nov. subfam.

Tests coiled in all stages; interior structure simple (non-labyrinthic); alveolar hypodermis lacking.

Type genus: *Haplophragmoides* CUSHMAN, 1910.

#### Subfamily II. *Lituolinae* s. str. emend. MAYNC, (*partim* BRADY).

As *Haplophragmoidinae* but spire uncoiling in the adult.

Type genus: *Lituola* LAMARCK, 1804 (= *Haplophragmium* REUSS et auct.)

#### Subfamily III. *Spirocyclininae* MAYNC, 1949.

Interior structure more or less labyrinthic; walls and septa divided by ramifying anastomosing channels; presence of an alveolar-reticulate hypodermis (honeycomb pattern) beneath epidermal coating.

Type genus: *Spirocyclina* MUNIER-CHALMAS, 1887.

## DISCUSSION OF GENERA

### I. *Haplophragmoidinae*.

In 1910, CUSHMAN split up the heterogeneous group of *Haplophragmium-Trochammina* and established the new genus *Haplophragmoides*, with *Nonionina canariensis* D'ORB., 1839, as genotype (CUSHMAN, 1910, p. 99). *Haplophragmoides* was proposed to include completely and planispirally coiled tests the texture of which exhibits a varying amount of foreign agglutinated particles and cement. The genus presents a non-labyrinthic wall structure and a simple apertural slit at or near the base of the septal face.

The new genus *Labrospira* HÖGLUND, 1947, was separated from *Haplophragmoides* CUSHMAN emend. HÖGLUND (HÖGLUND, 1947, p. 133, 141) by reason of differences in the position of the aperture. The forms showing the apertural fissure at the base of the septal face (interio-marginal) were referred to *Haplophragmoides*, those possessing an apertural slit within the septal face (interio-areal) to *Labrospira*. *Labrospira* HÖGLUND was recently shown to be in synonymy with *Cribrostomoides* CUSHMAN, 1910, and is invalid (FRIZZELL and SCHWARTZ, 1950).

<sup>11</sup> The derivation of *Pseudocyclammina* from *Cyclammina* is, moreover, chronogenetically impossible as *Pseudocyclammina* occurs much earlier in the geological time scale than *Cyclammina*.



The genus *Cribrostomoides* was erected by CUSHMAN, 1910, based on *Haplophragmium latidorsatum* BRADY (*partim*) (non BORNEMANN) (BRADY, 1884, Pl. 34, fig. 9), a form which was designated as *Cribrostomoides bradyi* CUSHMAN (CUSHMAN, 1910, p. 109, text figs. 167a-b). Young specimens of *Cribrostomoides* show a simple crescentiform aperture at or near the base of the septal face and can, therefore, not be differentiated from *Haplophragmoides* CUSHMAN. In later stages, however, this apertural slit becomes subdivided by tooth-like processes, as a result of which the aperture in the adult consists of a horizontal series of openings.

In 1947, HÖGLUND split up the genus *Haplophragmoides* CUSHMAN, 1910, and created the new genus *Labrospira* (see above). *Cribrostomoides bradyi* CUSHMAN was placed in synonymy with *Haplophragmoides subglobosum* (SARS) CUSHMAN, 1910, and included in the new genus *Labrospira*, with *L. subglobosa* (SARS) as type. Such an act of replacing an existing genus by a new one is nomenclaturally inadmissible unless the former is a *nomen nudum* or proved to be a homonym, neither of which is the case here. Accordingly, the writer is in full agreement with FRIZZELL and SCHWARTZ that *Labrospira* HÖGLUND, 1947, is invalid.

We do, however, not support the above-mentioned two authors with regard to their proposal to separate generically the Cretaceous species of *Cribrostomoides* from the recent *Cribrostomoides bradyi* CUSHMAN. The known Cretaceous species, namely *Cribrostomoides cretacea* CUSHMAN and GOUDKOFF (1944) and *Cribrostomoides trinitatis* CUSHMAN and JARVIS (1928), are referred by FRIZZELL and SCHWARTZ to their new genus *Barkerina*. The genotype, *Barkerina barkerensis* FRIZZELL and SCHWARTZ, 1950, from the Albian Walnut clay of Texas, differs from *Cribrostomoides* in having multiple but interio-marginal apertures and transverse partitions (septula) of the chambers, while *Cribrostomoides* lacks this subdivision into chamberlets and displays interio-areal apertures. Thanks to the courtesy of DON L. FRIZZELL, the writer was able to study and thin-section topotype specimens of *Barkerina barkerensis*, and he fully agrees with the given characteristics of this genus. He strongly objects, however, that for instance *Cribrostomoides trinitatis*

CUSHMAN and JARVIS from Lizard Springs, Trinidad,<sup>12</sup> is referred to *Barkerina*, as all the thin-sectioned topotype specimens of this species lack transverse partitions but exhibit simple undivided chambers (see Text fig. B - 1). Some rare specimens at hand show a *Recurvovoides*-like coiling instead of the usual planispiral one. It is certainly not warranted to unite *Cribrostomoides trinitatis* CUSHMAN and JARVIS and the internally different genus *Barkerina*. On the contrary, the excellent thin-sections of *Cr. bradyi* CUSHMAN, given by L. G. HENBEST (HENBEST, 1931, Pl. 12, figs. 1 and 2 [compare Text fig. B - 2]), indicate beyond a doubt that this recent species and *Cr. trinitatis* CUSHMAN and JARVIS possess a completely identical interior structure (undivided chambers). Both forms positively belong to the same genus *Cribrostomoides* CUSHMAN.



Text Fig. B). The interior structure of the genus *Cribrostomoides*.

- 1) *Cr. trinitatis* CUSHMAN and JARVIS (topotype specimen).
- 2) *Cr. bradyi* CUSHMAN (after L. G. HENBEST, 1932, Pl. 12, fig. 1).

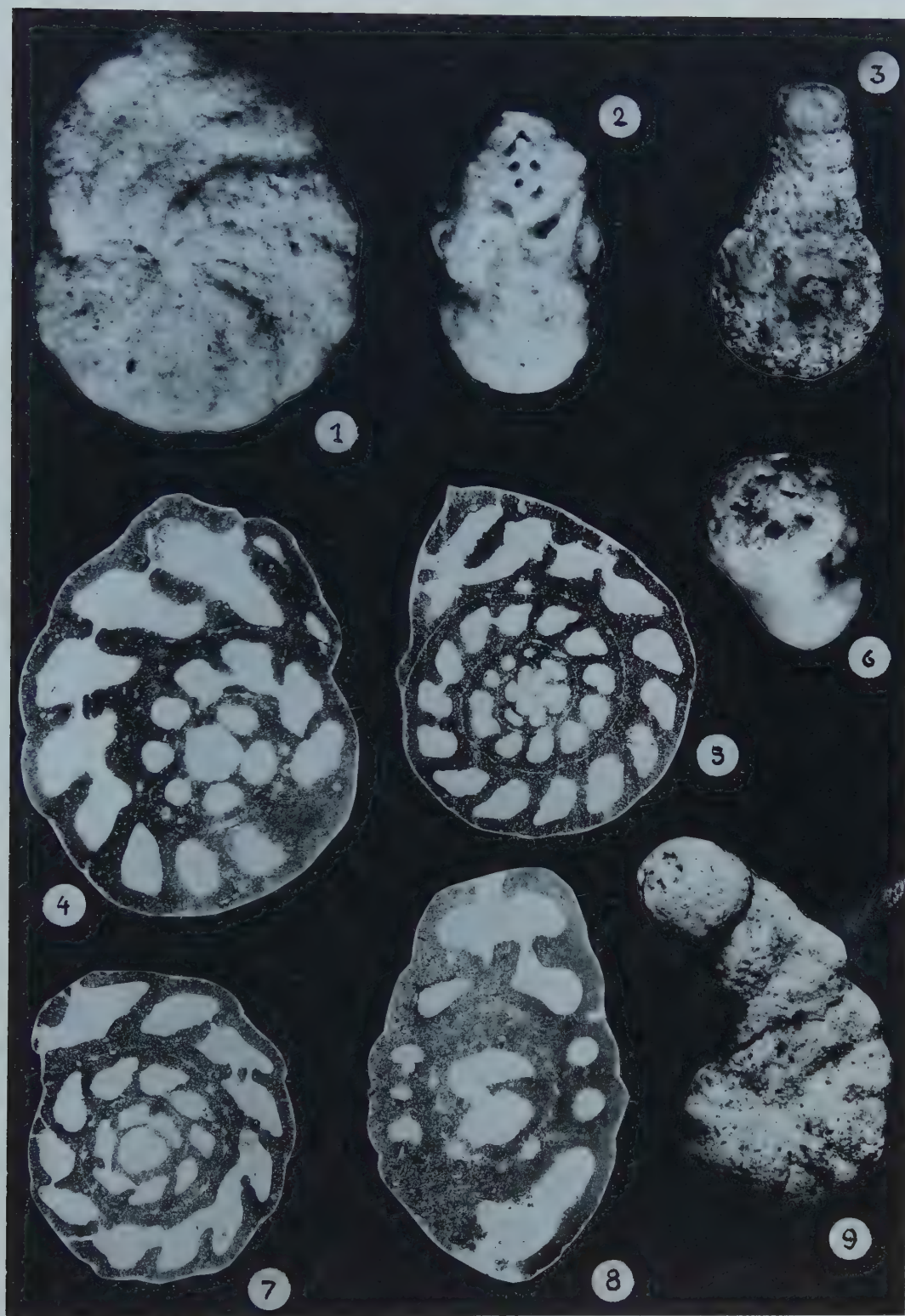
*Cribrostomoides kyushuense* ASANO, 1950, from the Miocene Tsuma formation of Japan, is reported to differ from *Cr. bradyi* in showing an apertural slit with simple lateral projections, instead of a multiple aperture caused by tooth-like processes (ASANO, 1950, p. 77). As recently shown by FRIZZELL and SCHWARTZ, the apertural characters of the genus *Cribrostomoides* are, however, rather variable (simple curved slit; dentate slit; multiple), and obviously form no constant

<sup>12</sup> The writer was fortunate to receive some topotype specimens of *Cribrostomoides trinitatis* CUSHMAN and JARVIS from H. H. RENZ-RENTZ, Mene Grande Oil Co., Caracas.

#### EXPLANATION OF PLATE 9

FIGS.		PAGE
1-8.	<i>Lituola nautiloidea</i> Lamarck. Topotype material from Meudon, France. Campanian Cretaceous.	
1.	Neotype, $\times 27$ .	46
2.	Same specimen as shown in Fig. 1; view of aperture, $\times 27$ .	46
3.	Paratype, $\times 15$ ; uncoiled specimen.	46
4.	Median section displaying the simple structure of walls and septa, $\times 26$ .	46
5.	Median section showing the simple (non-labyrinthic) interior structure, $\times 18$ .	46
6.	Same specimen as shown in Fig. 3; apertural view, $\times 27$ .	46
7.	Median section, $\times 18$ .	46
8.	Axial section of uncoiled specimen, $\times 27$ .	46
9.	<i>Lituola taylorensis</i> Cushman and Waters. Topotype specimen (Taylor marl Marquez Dome, Leon Cty., Texas, USA, $\times 15$ .	46





Maync, Lituolidae





Maync, Lituolidae



criterion to define either the genus or different species (FRIZZELL and SCHWARTZ, 1950). Disregarding the specific determination of this Japanese form for the present, the writer wishes to stress here the recorded occurrence of a Tertiary representative of the genus *Cribrostomoides* CUSHMAN.

No specimens of *Cr. cretacea* CUSHMAN and GOUDKOFF or *Cr. kyushuense* ASANO were available, and, therefore, nothing can be stated as to the interior structure of these species. For the time being, *Cribrostomoides cretacea* CUSHMAN and GOUDKOFF is also grouped with the genus *Cribrostomoides*.

The genus *Barkerina* FRIZZELL and SCHWARTZ, 1950, placed by its authors in the *Haplophragminae* of the *Lituolidae*, differs from *Haplophragmoides* in having multiple apertures and, first and foremost, in possessing subdivided chambers. This "Alveolinellid" feature is so alien to any form of the *Haplophragmoides*-group, that the assignation of *Barkerina* to a lituolid subfamily is strongly doubted by the author.

*Recurvoides* EARLAND, 1934, based on the recent species *R. contortus* EARLAND, is a *Cribrostomoides*-like form which, instead of showing a planispiral coiling, exhibits a change of the axis so that a coiling in different planes results. This principle of a streptospiral coiling which the writer regards as being a fundamental taxonomic feature was recognized in other Lituolids (*Bulbophragmium*, *Bulbobaculites*).

The genus *Trochamminoides* CUSHMAN, 1910, is based on the Cretaceous form *Trochammina proteus* KARRER, 1865 (CUSHMAN, 1910, p. 97). According to CUSHMAN's diagnosis, *Trochamminoides* is "typically planispiral." The original figures given by F. KARRER (KARRER, 1865, Pl. 1, fig. 1-8) clearly disclose, however, that the planispiral coiling is by no means typical; most specimens depicted show a trochoid or strep-

tospiral coiling. BRADY (1884, p. 341) and CUSHMAN (1910, p. 98), therefore, proposed to designate KARRER's figure 8 as type figure, and the genus *Trochamminoides* CUSHMAN is actually based on it. Apparently, KARRER's figures 1-6 represent different genera but his figure 7 certainly depicts a chambered form and figure 8 shows an irregular coiling in varying planes.

The fact that the early portion in *Trochamminoides* may not always be subdivided into chambers suggests that this form is derived from *Ammodiscus*. *Trochamminoides* may, consequently, be interpreted as transitional between an *Ammodiscus*-like form and a primitive Lituolid (*Haplophragmoides* type) with a distinctly subdivided test. *Trochamminoides* is generally placed among the *Lituolidae*.

## II. Lituolinae s. str.

*Ammobaculites* CUSHMAN, 1910, based on *Spirolina agglutinans* D'ORBIGNY, 1846, comprises arenaceous tests showing a close planispiral initial coil and a considerable uncoiled portion. Its simple terminal, more or less rounded aperture differentiates it from the coarsely arenaceous representatives of *Lituola* LAMARCK (*Haplophragmium*, olim).

In 1947, H. HÖGLUND erected the new genus *Ammo-scalaria* for the forms of *Ammobaculites* disclosing a secondary formation of the septal walls and an apertural neck (genotype: *Haplophragmium tenuimargo* BRADY, 1884).

*Frankeina* CUSHMAN and ALEXANDER, 1929 (genotype: *F. goodlandensis* CUSHMAN and ALEXANDER), is interpreted as a derivate of *Ammobaculites* CUSHMAN, exhibiting a largely reduced planispiral early coil with an uncoiled portion triangular in section. The uniserial chambers show a frondicularian type (inverted V-shape), and the aperture is a simple terminal opening.

## EXPLANATION OF PLATE 10

FIGS.		PAGE
1-6.	<i>Lituola difformis</i> Lamarck. Topotype material from Meudon, France. Campanian Cretaceous.	
1.	Neotype, $\times 27$ .	37
2.	Same specimen as shown in Fig. 1; edge view, $\times 27$ .	37
3.	Same specimen as shown in Figs. 1 and 2; view of the cribrate aperture, $\times 45$ .	37
4.	Median section revealing simple interior structure like <i>Lituola nautiloidea</i> Lamarck, $\times 27$ .	47
5.	Subaxial section, $\times 27$ .	47
6.	Very shallow section displaying compact, non-labyrinthic structure of walls and septa, $\times 27$ .	47
7-10.	<i>Bulbophragmium aequale</i> (Reuss). Type figures ex Reuss, 1860, Sitz. ber. Akad. Wiss. Wien, vol. 40, Pl. XI, figs. 2 a-b, 3 a-b.	
7.	Form with typically streptospiral early coil.	46
8.	Same specimen as shown in Fig. 7; view of aperture.	46
9.	Specimen with twisted bulb-like initial spire.	46
10.	Same specimen as shown in Fig. 9; apertural view.	46
11-12.	<i>Spirolina grandis</i> Reuss. Type figures ex Reuss, 1854, Denkschr. K. Akad. Wiss. Wien, vol. 7, Pl. XXV, Figs. 14 and 14b.	
11.	Specimen showing regular early spire.	40
12.	Same specimen as shown in Fig. 11, edge view.	40
13-14.	<i>Bulbobaculites lueckeii</i> (Cushman and Hedberg). Type figures ex Cushman and Hedberg, 1941, Contr. Cushman Lab. For. Research, vol. 17, pt. 4, Pl. 21, Figs. 4a-b. Upper Cretaceous Colon shale, Colombia, S.A., $\times 76$ .	
13.	Specimen exhibiting irregular bulb-like initial coil.	47
14.	Same specimen as shown in Fig. 13; apertural view.	47



The genus seems to become exterminated in the Cretaceous.

*Triplasia* REUSS, 1854, with the genotype *T. murchisoni* REUSS, is a *Frankeina* lacking the coiled initial portion altogether in the megalospheric form. *Frankeina* and *Triplasia* exhibit a triangular section and a simple terminal aperture, sometimes with a neck.

An aberrant form of *Triplasia murchisoni* (REUSS) BEISSEL, 1891 (*partim*), showing a quadrangular transverse section instead of a triangular one, has been taken as genotype of the genus *Tetraplasia* BARTENSTEIN and BRAND, 1949 (BARTENSTEIN and BRAND, 1949, p. 672). Both forms are transitional and, accordingly, very closely allied, so that the genus-status of *Tetraplasia* seems questionable.

*Flabellamina* CUSHMAN, 1928, based on *F. alexanderi* CUSHMAN, differs from *Frankeina* (as *Ammomarginulina* from *Ammobaculites*) in showing a much compressed test and an elongate simple aperture. Like *Frankeina*, *Flabellamina* develops low chevron-shaped chambers in the uncoiled portion.

*Ammomarginulina* WIESNER, 1931, was based on a recent species, *Ammomarginulina ensis* WIESNER, 1931. It differs from *Ammobaculites* CUSHMAN merely in being considerably flattened instead of circular-oval and in having a simple elongate aperture. Mesozoic, Tertiary and Recent species have since been described many of which may only represent mechanically compressed species of *Ammobaculites*. Applying the above-given characteristics of H. WIESNER's genus, the Carboniferous form *Ammobaculites compressa* CUSHMAN and WATERS, 1927, (See: ELLIS and MESSINA, 1940, etc.) should be referred to *Ammomarginulina*. On this account the range of the latter genus becomes greatly extended.

Another close derivate of *Ammobaculites* which should be given subgeneric status, is the Cretaceous genus *Buccicrenata* LOEBLICH and TAPPAN, 1949, based on *Ammobaculites subgoodlandensis* VANDERPOOL, 1933 (LOEBLICH and TAPPAN, 1949). Externally, *Buccicrenata* bears the characteristics of *Ammomarginulina* WIESNER from which it differs in its crenulate aperture (vertical elongate slit with lateral tooth-like processes). *Buccicrenata* is reported to reveal a labyrinthic interior, a statement which, however, probably rests upon a misinterpretation of the term labyrinthic: The arenaceous irregular thick walls and septa of many species of *Ammobaculites*, etc. do not imply the term labyrinthic inner structure as no anastomosing meandering channels are developed which characterize the alveolar-spongy appearance of the labyrinthic structure.

No figures of a section of *Buccicrenata* were reproduced by its authors and no topotype specimens were placed at the writer's disposal for a study of the interior structure. A definite answer as to the taxonomic position of the genus *Buccicrenata* LOEBLICH and TAPPAN can, therefore, not yet be given.

The genera *Phenacophragma* and *Stomatostoecha* have been grouped by their authors under the subfamily *Endothyriinae* (APPLIN, LOEBLICH and TAPPAN, 1950, p. 76), an alignment which — in view of the simple single-layered wall structure — cannot be supported. The simple (non-labyrinthic) and homogeneous inner structure and tendency of uncoiling prove that these genera belong to the *Lituolinae* s. str. Externally, both genera strongly recall the *Choffatella-Pseudocyclamina* group (APPLIN, LOEBLICH and TAPPAN, 1950, p. 76) but lack the reticulate hypodermis and/or labyrinthic interior. Another characteristic feature of *Phenacophragma* is the presence of short intermediate partitions between the normal septa projecting from the periphery.

*Lituola* LAMARCK, 1804, emend. MARIE, 1941, emend. MAYNC.

Genotype: *Lituola nautiloidea* LAMARCK, 1804.

Neotype: Pl. 9, fig. 1.

Paratypes: Pl. 9, figs. 3-5, 7, 8.

Diagnosis. Test arenaceous with a varying amount of exogenous material and cement (texture). Planispirally coiled in early stages, uncoiling in the adult. Aperture multiple, cribrate. Interior structure of walls and septa simple (non-labyrinthic).

Included in the emended genus *Lituola* LAMARCK are all the forms previously referred to either *Lituola* LAMARCK or *Haplophragmium* REUSS *et auctorum* disclosing a planispiral initial coil; the species of *Haplophragmium*, *olim*, exhibiting a streptospirally coiled early portion are placed in the new genus *Bulbophragmium* n. gen. (see below).

The outside features of *Lituola* LAMARCK resemble those of *Ammobaculites* CUSHMAN but *Lituola* is characterized with multiple apertures (see Pl. 9, figs. 2 and 6). From the externally similar genus *Pseudocyclamina* YABE and HANZAWA, 1926 (with which it has been often confounded), *Lituola* LAMARCK differs in having a non-labyrinthic interior structure and in lacking a reticulate hypodermal layer (see Pl. 9, figs. 4, 5, 7, 8; Pl. 10, figs. 4, 5, 6; Pl. 11, figs. 1, 2; Pl. 12, fig. 11).

*Bulbophragmium* n. gen.

Genotype: *Haplophragmium aequale* REUSS, 1860.

Type figure: REUSS, 1860, Pl. XI, fig. 2a (reproduced on Pl. 10, figs. 7-10 of this paper).

Diagnosis. Test arenaceous, crozier-shaped, the early portion streptospirally coiled (irregular twisted spiral coiled in varying planes); uncoiled and straight in later stages; interior structure simple (non-labyrinthic); aperture cribrate.

*Bulbophragmium* n. gen. differs from the *Lituola* group (incl. *Haplophragmium*, *olim*) in being not planispirally coiled in the young but displaying an irregular coil (axis of initial coiling changing its direction).

This morphologically different mode of coiling between *Lituola* and *Bulbophragmium* is also indicated



in the *Ammobaculites* group. According to the original definition, the early portion of *Ammobaculites* CUSHMAN, 1910, is "coiled in one plane" (CUSHMAN, 1910, p. 114). *Ammobaculites lueckei* CUSHMAN and HEDBERG, 1941, from the Upper Cretaceous Colon shale of Colombia, however, shows an irregular early coiling similar to the streptospiral coil of *Bulbophragmium* n. gen. (CUSHMAN and HEDBERG, 1941, Pl. 21, fig. 4a). Although we do not know of many other species of *Ammobaculites* with this mode of coiling in varying planes,<sup>13</sup> we feel justified on the reasons outlined above in erecting a new genus for this (and future) forms deviating from the *Ammobaculites* norm. In harmony with the etymology of the similarly constructed genus *Bulbophragmium* the term *Bulbobaculites* n. gen. is herewith proposed, with *Ammobaculites lueckei* CUSHMAN and HEDBERG, 1941, as genotype (type figure: CUSHMAN and HEDBERG, 1941, Pl. 21, fig. 4a; reproduced on Pl. 10, figs. 13, 14 of this paper).

Another species of *Bulbobaculites* n. gen. is the classic *Spirolina aequalis* ROEMER (type figure in ROEMER, 1841, Pl. 15, fig. 27) which exhibits the typical streptospiral early coil, shows simple (non-labyrinthic), though very thick walls and septa, and a simple terminal aperture. Unfortunately, no topotypes are available of this form which hindered the writer from selecting it as genotype of *Bulbobaculites* n. gen.

Because of its regular planispiral early coil the form identified as *Ammobaculites* cf. *lueckei* CUSHMAN and HEDBERG from the Lizard Springs formation of Trinidad (CUSHMAN and RENZ, 1946, Pl. 2, fig. 7) cannot be referred to the genuine species of the Colon shale of Colombia.

The genus *Ammobaculoides* PLUMMER, 1932, placed by its author among the *Lituolidae*, exhibits a biserial stage between the juvenile coil and the adult uniserial chambers, on account of which it evidently evolved from a *Spiroplectammina*-like form (*Textulariidae*).

Some comparative material kindly put at the writer's disposal shows that neither *Ammoastuta* CUSHMAN and BRÖNNIMANN, 1948, nor *Praeammoastuta* n. gen. BURSCH (M.S.) (to be described by J. G. BURSCH in a special paper) has an initial coiled portion; their chambers are curved-uniserial, and their alignment with the *Lituolidae* is, therefore, not justified.

According to P. MARIE, *Cribosepirella* MARIE, 1941, differs from LAMARCK's genus *Lituola* in its general form, its weakly pronounced sutures, its involute chambers, and its vermiculate apertural openings. The writer, who studied numerous thin-sections of *Cribosepirella difformis* (LAMARCK) from the type locality (some of which are figured on Pl. 10, figs. 4-6), is of opinion that the genus *Cribosepirella* MARIE is super-

fluous from a nomenclatural point of view. Its interior structure is identical with that one in *Lituola* LAMARCK (see Pl. 9, figs. 1-8; and Pl. 10, figs. 1-6), and the slight external differences with *Lituola* are not important enough to warrant a new genus. Any higher-than-subgenus status of *Cribosepirella* MARIE, 1941, is, therefore, rejected.

The genus *Daxia* CUVILLIER and SZAKALL, 1949, is considered by its authors to be an intermediate form of the genera *Haplophragmoides* and *Cyclammina* and is regarded to be a close ally of *Choffatella* SCHLUMBERGER (CUVILLIER and SZAKALL, 1949, p. 8).

That *Daxia* has nothing in common with *Choffatella* or with any choffatelloid form has already been pointed out (MAYNC, 1949, p. 535). *Daxia* lacks a reticulate hypodermis and a labyrinthic interior structure (see Pl. 9, fig. 3, and Pl. 11, fig. 4), and, therefore, cannot be aligned with *Cyclammina* or with any member of the *Spirocyclininae*. Its interior structure shows a *nummulitoid* spire which was thought at first sight to be endowed with a primitive obscure canal system, on account of which *Daxia* was supposed by the author to represent an ancestral, though finely arenaceous form of *Nummulites*. Having not enough topotype specimens of *Daxia cenomana* CUVILLIER and SZAKALL (genotype) at hand to carry out a thorough study of this interesting feature, the writer refrains from drawing definite conclusions as to the systematic position of *Daxia*. If no trace of a canal system can be proved, however, *Daxia* is nothing else than a completely involute multi-chambered species of *Haplophragmoides*, can hardly be maintained as an independent genus and must be given subgenus-rank.

A publication by P. BRÖNNIMANN (1951a) contains the new lituolid genus *Discamminoides* BRÖNNIMANN, 1951, with genoholotype *D. tobleri* BRÖNNIMANN, 1951.

Externally, *Discamminoides* is similar to *Haplophragmoides* or *Cyclammina* but shows a tendency to uncoil which is typical of the *Lituolinae* s. str. In juvenile specimens the aperture is apparently simple but supposed to become multiple (cribrate?) in later ontogenetic stages. The interior of the test is subdivided by simple, slightly curved septa; the wall structure is simple (non-labyrinthic). Characteristic of the new genus, however, is the fact that the lumina are peripherally filled by a finely arenaceous matrix interlaced by tubular channels. These passages (arranged in one or two rows) lead to the roof of the chambers but do not pierce the homogeneous walls.

These careful observations of BRÖNNIMANN thus reveal that *Discamminoides* — with its simple walls and septa and its alveolar marginal filling of the chambers — is an intermediate form between the group of the simple *Lituolinae* s. str. and the truly labyrinthic genera composing the *Spirocyclininae*. The genus *Discamminoides* as described by BRÖNNIMANN, however, differs in the most important morphological-taxonomic

<sup>13</sup> The Carboniferous *Ammobaculites stormi* CUSHMAN and WATERS, 1928, the early coil of which does not coincide with the plane in which the later rectilinear chambers are arranged, is presumably an endothyroid form.

feature, namely in the wall structure, from *Alveolophragmium* or any other spirocyclinine genus (which show a reticulate hypodermis and/or a vesicular wall structure throughout), while *Discaminoides* definitely possesses simple homogeneous walls and lacks an alveolar layer beneath the epidermis. On this account, the writer gives preference to an alignment of *Discaminoides* with the *Lituolinae* s. str.

Some topotype specimens of *Discaminoides tobleri* BRÖNNIMANN from the Lower Miocene Cruse clays of Trinidad (A.T.O. wells Nos. 519 and 522) were kindly furnished by P. BRÖNNIMANN. Unfortunately, only one of the six thin-sectioned specimens shows traces of the peculiar interior structure on which the new genus is based, but which seems to be not developed in many cases. Most of the prepared sections are forms with a simple (non-alveolar) interior structure, but no spongy filling of the lumina could be detected. These forms positively belong to the group of the *Lituolinae* s. str.

### III. Spirocyclininae.

The genus *Alveolophragmium*, erected in 1936 by Z. STSCHEDRINA, was based on a new species, *A. orbiculatum* STSCHEDRINA collected from recent marine deposits of the Bay of Peter The Great, off Vladivostok (STSCHEDRINA, 1936, p. 314). The original diagnosis gives a clear description of the alveolar-reticulate wall structure of this genus which is the only differential criterion with *Haplophragmoides* CUSHMAN. *Alveolophragmium* was correctly referred by its author to the labyrinthic group of the *Lituolidae* (*Lituolinae* auct.). Its alignment with the non-labyrinthic genera (see f. i. CUSHMAN's classification) is incomprehensible.

A paper wherein some species of this genus are discussed by the writer and a new species from the Tertiary of Venezuela will be described is in preparation.

*Cyclammina* BRADY, 1876 (genotype: *C. cancellata* BRADY, 1876), resembles externally *Lituola* LAMARCK or *Haplophragmoides* CUSHMAN but possesses both apertural pores and an interio-marginal slit. The inner structure of *Cyclammina*, however, reveals a reticulate hypodermis (see Pl. 11, figs. 5-8) beneath the imperforate epidermal coating and an excessive development of a labyrinthic structure of both walls and septa, with its characteristic intricate network of irregular dichotomously branched passages which intercommunicate by anastomosis (see Pl. 11, figs. 5, 6). As a consequence of this exuberant labyrinthic growth most of the chamber-cavities become obliterated.

The best description of the genus as well as excellent illustrations showing the interior structure of *Cyclammina cancellata* BRADY were given by H. B. BRADY himself (BRADY, 1884, p. 350-352; Pl. XXXVII, Figs. 11-16).

In accordance with the concept of the term "labyrinthic structure" (BRADY, 1884, p. 352), the writer differentiates between

1) *Simple interior structure*: Tests showing a compact wall structure (agglutination of foreign material, with size of incorporated particles and amount of cement varying),

and 2) *Labyrinthic interior structure*: Tests exhibiting a perplex spongy wall structure (interlaced dendritic pattern of channels normal to the wall).

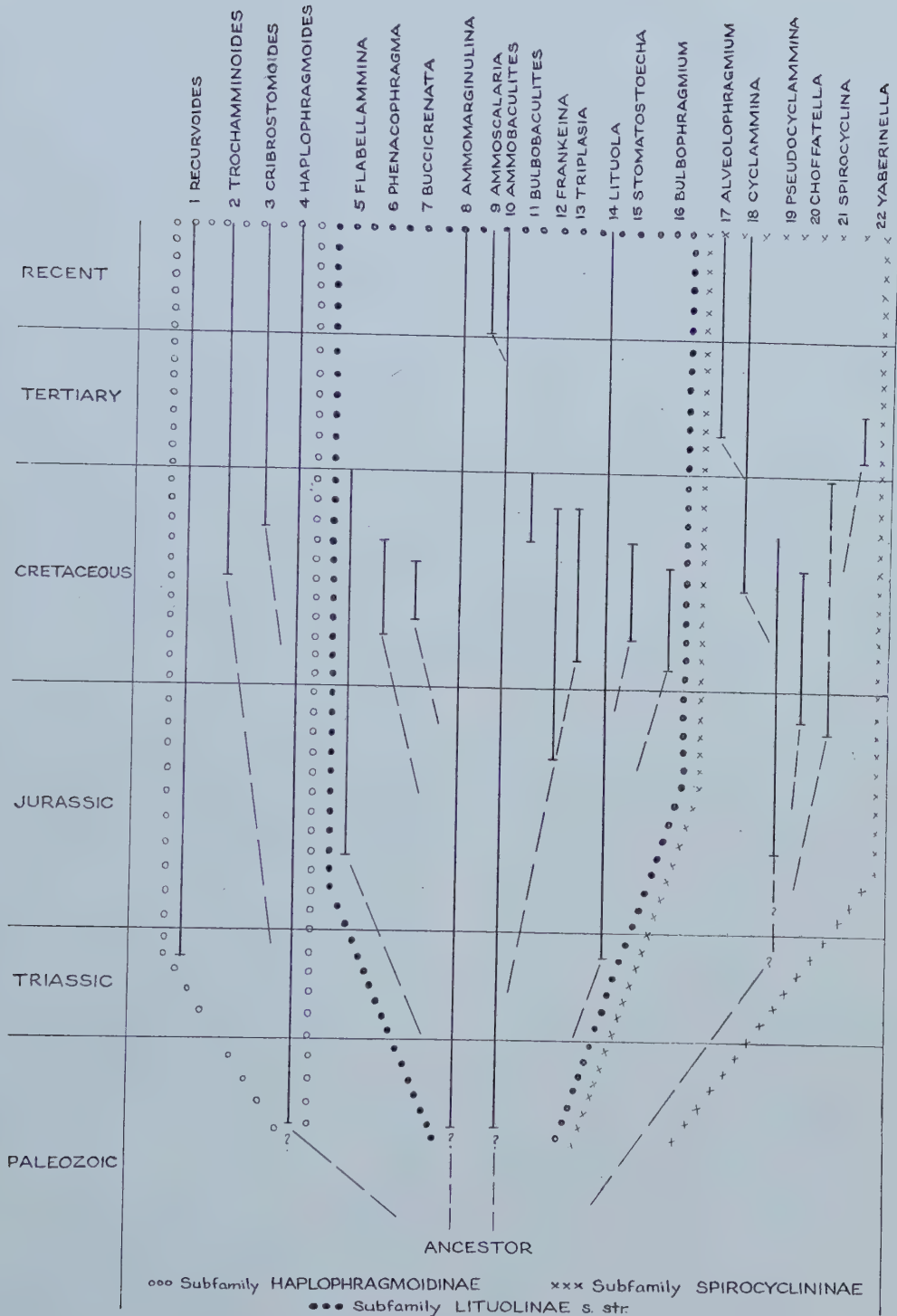
The attribute "labyrinthic" is thus only applied to the cancellated structure of the walls and septa which may often show an excessive thickness. It is, in other words, not the chambers which are labyrinthic but the walls and septa of the test.

In an interesting study recently published P. BRÖNNIMANN suggests that — at least in the case of *Cyclammina* — the term "labyrinthic internal structure" be replaced by "alveolar internal structure," since alveoles of primary, secondary, and tertiary order can be discriminated (BRÖNNIMANN, 1951b). These alveoles examined in the test of *Cyclammina* are, in other words, arranged conformable to a methodical plan, not at random, on account of which the term "labyrinthic" is held to be misapplied. As shown above, however, our concept of the term "labyrinthic structure" designates the cancellous or spongy character of walls and septa, in opposition to the densely constructed ones of the simple internal structure. Notwithstanding the fact that alveoles of a different order were found to build up systematically the tubular passages which characterise the labyrinthic structural type, yet the general impression of the heterogeneous wall structure is an intricately baffling maze of channels which exactly reflects the meaning of the Greek word *labyrinthos* (see: BRÖNNIMANN, 1951b, figs. 4, 7, 8, p. 759). Whether the typically spongy wall character is described as labyrinthic, alveolar, vacuolar, vesicular, etc. is, after all, rather insignificant, and a discussion along such lines — at least in the present stage of knowledge — seems to miss the crucial point of the problem.

The genus *Pseudocyclammina* YABE and HANZAWA, 1926, based on *Cyclammina lituus* YOKOYAMA, 1890, is a *Lituola*-like form disclosing, however, a reticulate hypodermis and a coarsely labyrinthic structure of walls and septa which, in some species, is exuberantly developed at the expense of the lumina (see f. i.: YOKOYAMA, 1890, Pl. V, fig. 7; YABE and HANZAWA, 1926, Pl. II; PFENDER, 1938, Pl. XIII; HENSON, 1948, Pls. IX, XIII; Pl. 12, fig. 1 of this paper). The close initial planispiral coil is followed by an uncoiled adult stage. The cribrate aperture consists of numerous pores irregularly arranged on the septal face (see YOKOYAMA, 1890, Pl. V, fig. 7).

As shown by F. R. S. HENSON (1948) the reticulate hypodermis is quite irregular and is underlain by a conspicuously thick developed labyrinthic layer (*Lituus* type). Some other forms of *Pseudocyclammina* show a more regular interior structure similar to that of *Choffatella* SCHLUMBERGER. The species *Ps. sequana*





Text Fig. C. Chronogenesis and supposed Phylogenetic Relationship of the Lituolidae.

(Note by the Editor: The stratigraphic range of *Recurvovides* is from Middle Jurassic (Dogger) to Recent, not as shown above from Upper Triassic to Recent. See: R. WEYNSCHENK, 1951, Jour. Paleont., vol. 25, pp. 793 and 795.)

(MERIAN) and *Ps. personata* TOBLER are, as a matter of fact, transitional between the coarsely labyrinthic *Ps. lituus* (YOKOYAMA) and the finely built genus *Choffatella* revealing delicate regularly pierced septa and a thin labyrinthic layer (see e. g. TOBLER, 1925, Pl. XXVII; TOBLER, 1928, Pl. XXIV; MAYNC, 1949, Pls. XI-XII and Pl. 12, figs. 3, 4). The writer has shown that both *Pseudocyclammina* and *Choffatella* may uncoil in adult stages (MAYNC, 1949, p. 538 [see Pl. 11, fig. 9; and Pl. 12, fig. 1]). Except for the subtle interior structure of *Choffatella* and that fact that this form has more chambers per whorl than *Pseudocyclammina*, there is the difference of their apertures which justifies a generic distinction: *Pseudocyclammina* shows a cribrate aperture with coarse openings distributed all over the septal face (see type figure in YOKOYAMA, 1890, Pl. V, fig. 7), and *Choffatella* possesses a vertical series of pores (see type figure in SCHLUMBERGER, 1904, Pl. XVIII, fig. 3).

Some specimens of *Lituola rugosa* D'ORBIGNY, 1850 (1847 MS) (non PARKER, JONES and BRADY, 1871) from the Cenomanian of Île Madame, Bay of Biscay (Charente, France), were put at the writer's disposal by the courtesy of J. CUVILLIER, Paris. The prepared thin-sections reveal a typically labyrinthic structure of walls and septa<sup>14</sup> (see Pl. 12, figs. 8-10) on account of which this form is removed from the *Lituola* group and referred to *Pseudocyclammina rugosa* (D'ORB.).

The species nearest to *Pseudocyclammina rugosa* (D'ORB.) is the Upper Jurassic *Ps. virguliana* KOEHLIN (KOEHLIN, 1942, Pl. VI, fig. 2; see also Pl. 12, fig. 5) from which it differs in its thicker developed walls and septa and in its large inflated chambers (5-6 in the last whorl); *Ps. virguliana* KOEHLIN shows 6-7 chambers in the last-formed coil. Externally, *Ps. rugosa* (D'ORB.) is sturdier and more massive in shape and has a broadly rounded periphery similar to *Ps. lituus* (YOKOYAMA) YABE and HANZAWA, while *Ps. virguliana* KOEHLIN exhibits a more or less subacute margin. Examined specimens of *Ps. rugosa* (D'ORB.) are of considerable size, viz. 3.1 to 3.8 mm in length (last whorl) which roughly corresponds to the dimensions of *Ps. lituus* (see MAYNC, 1938, p. 59); the coiled portion of *Ps. virguliana* KOEHLIN is of much smaller size (1.1 to 2.0 mm).

The morphological differences as well as the different stratigraphic position prevent us from identifying the Cenomanian species *Ps. rugosa* (D'ORB.) with any known form of *Pseudocyclammina* YABE and HANZAWA.

*Ps. rugosa* (D'ORB.) is the youngest hitherto known representative of the genus *Pseudocyclammina* which was believed once to be a diagnostic Upper Jurassic-Lower Cretaceous marker.

The occurrence of *Pseudocyclammina lituus* (YOK.) and *Ps. n. sp.* in the Lower Cretaceous of the Carib-

bean Region has been recorded by the author (MAYNC, 1949). A special paper on these forms is in preparation.

While it has certainly been justified in referring *Choffatella cyclamminoides* SILVESTRI, 1925, to the genus *Pseudocyclammina* YABE and HANZAWA, 1926 (YABE and HANZAWA, 1926), there have risen very strong doubts whether the other two Sumatran forms, viz. *Lacazina lamellifera* SILVESTRI, 1925 and *Loftusia bemmeleni* SILVESTRI, 1932, actually belong to the same morphological unit as was proposed by SH. HANZAWA (HANZAWA, 1947, p. 7). A. SILVESTRI, P. T. COX, and others have ventured the opinion that "*Lacazina*" *lamellifera* SILVESTRI, 1925 [= *Loftusia lamellifera* (SILVESTRI), SILVESTRI, 1932] might morphologically be placed near the late Cretaceous group of *Loftusia ex gr persica* BRADY. COX suggests that *Loftusia lamellifera* (SILV.) be regarded as intermediate between *Pseudocyclammina* and *Loftusia* (COX, 1937, p. 438).

G. A. DE NEVE, Bandoeng, has had the kindness to send the writer some *Loftusia*- and *Pseudocyclammina*-bearing rock samples from Sumatra. Although the limestone containing *Loftusia* is badly crushed and the fossils deformed, the author is convinced now that *Loftusia lamellifera* (SILVESTRI) cannot be referred to as a species of *Pseudocyclammina* YABE and HANZAWA, and the view expressed by COX (see above) is fully supported.

Just recently, Professor H. YABE kindly sent the writer reprints of two papers in which these Sumatran forms are discussed (YABE, H., 1946, On some Fossils from the Saling Limestone of Goemai Mountains, Palembang, Sumatra, parts I and II. Proceedings of the Japan Academy, vol. 22 (1946), Nos. 6 and 8). From a study of thin-sections of rock specimens from the Gumai Mountains, H. YABE concludes that both "*Loftusia*" *lamellifera* (SILVESTRI) and "*Loftusia*" *bemmeleni* SILVESTRI should be removed from the genus *Loftusia* BRADY. The new genus *Paracyclammina* YABE, 1946, with *Loftusia bemmeleni* SILVESTRI, 1932, as genotype is proposed for these forms which are stated to show close affinities with *Pseudocyclammina* YABE and HANZAWA. *Paracyclammina* differs from the similar genus *Pseudocyclammina* in showing a great number of closely coiled whorls with very oblique (*Loftusia*-like), thick perforated septa. H. YABE suggests that *Paracyclammina lamellifera* (SILVESTRI) might be the microspheric generation of *Paracyclammina bemmeleni* (SILVESTRI).

True specimens of *Pseudocyclammina lituus* (YOKOYAMA) YABE and HANZAWA, associated with *Trocholina* (*Coscinoconus*) *alpina* (LEUPOLD), *Lovčeniopora* sp. etc., are, however, represented in some samples from the Gumai Mountains, Palembang District, South Sumatra, and from Western Atjeh, North Sumatra.

In 1938, W. MOHLER described *Ammobaculites coprolithiformis* (SCHWAGER) var. *sequana* n. var. from the Lower Sequanian of the northwestern Jura Moun-

<sup>14</sup> This distinctive structure was already observed by M. REICHEL (1936) and F. R. S. HENSON (1948).



tains, Switzerland (See: ELLIS and MESSINA, 1940 etc.). This form is stated to be built up mainly of agglutinated tests of *Pseudocyclammina sequana* (MERIAN), and the aperture is reported to be either simple, stellate, or cribrate. It results from the original description that *Ammobaculites coprolithiformis* (SCHWAGER) var. *sequana* MOHLER shows a labyrinthic interior structure which is evident in the longitudinal section reproduced by MOHLER in his text figure 8 (p. 39). Both walls and septa are seen to be cancelled by ramifying channels and vesicles, in other words, exhibit a truly labyrinthic structure. On this account we believe that this form has wrongly been assigned to the genus *Ammobaculites* CUSHMAN and should be referred to *Pseudocyclammina* YABE and HANZAWA. As the attribute *sequana* is preoccupied by *Pseudocyclammina sequana* (MERIAN) we propose the new name *Pseudocyclammina ammobaculitiformis* n. sp. with *Ammobaculites coprolithiformis* (SCHWAGER) var. *sequana* MOHLER, 1938, as type.

In a recent paper, R. WEYNSCHENK reported the occurrence of *Pseudocyclammina lituus* YABE and HANZAWA in the Tirolian Alps (WEYNSCHENK, 1950, Pl. III, fig. 26). The mentioned form occurs in a reefal limestone derived from the Upper Jurassic "Vorfeld Breccia." This *Pseudocyclammina*-bearing limestone component is held to be of Upper Rhaetic-Liassic age on mere lithological evidence. R. WEYNSCHENK has had the kindness to send the writer two thin-sections of his rock specimen No. 107. Typical large specimens of thick-walled *Pseudocyclammina lituus* (YOK.) YABE and HANZAWA are present in these slides (one of them contains the specimen reproduced by R. WEYNSCHENK (Pl. III, fig. 26) which consist of an organic onkoidic limestone such as are characteristic of some Upper Jurassic breccias of the Swiss Alps. In his above-mentioned paper (as well as in his letters to the author) R. WEYNSCHENK clings to the concept that the *Pseudocyclammina*-bearing limestone in question is of Upper Rhaetic (or Liassic) age, an assignment which we frankly doubt until definite proofs are at hand. Associated with *Ps. lituus* (YOK.) YABE and HANZAWA are *Miliolidae*, *Textularia*, ?*Valvulamina* sp., etc., and specimens of a small multi-chambered form uncoiling in the adult. Its wall structure, however, cannot be made out on the forwarded thin-sections, though.<sup>15</sup> In the author's opinion, the faunal association in this limestone (which can hardly be distinguished from the widely distributed one in the Upper Jurassic of the Swiss Alps) points to a Jurassic (Malm) age. The presence of *Dasycladaceid* algae similar to *Clypeina* FAVRE and RICHARD and the occurrence of *Conicospirillina basilensis* MOHLER, *Globochaete alpina* LOMBARD, and *Eoithrix alpina* LOMBARD, reported by R. WEYNSCHENK

from the same rock specimen, decidedly favor an Upper Jurassic (Sequanian-Kimmeridgian) instead of a Rhaetic age. In the Swiss Alps, *Pseudocyclammina* has never been found up to this date in beds older than Callovian-?Bathonian, and *Ps. kelleri* HENSON is reported to occur in Callovian-Argovian strata of Iraq (HENSON, 1948, p. 17). Provisionally, until positive faunal proofs for a Rhaetic-Liassic age are presented, the genus *Pseudocyclammina* YABE and HANZAWA is not considered to appear before the Middle Jurassic (Callovian-Bathonian).

R. WEYNSCHENK published just recently a short note on two foraminifera from the Tyrolian Alps, viz. *Labyrinthina mirabilis* n. gen. n. sp. from the Upper Triassic, and *Recurvoides* cf. *trochamminiforme* HÖGLUND from the Dogger (Middle Jurassic) (WEYNSCHENK, 1951).

The new genus *Labyrinthina* WEYNSCHENK is placed in the lituolid family, although its test is sometimes typically attached to detrital particles. Its chambers appear to have a rather irregular outline, like some species of *Ammobaculites*, which, however, is evidently conformable to the more or less tangential plane of section. The wall structure is stated to be homogeneously agglutinated, without displaying tubular anastomotic passages etc. Consequently, the term "labyrinthic" as used by R. WEYNSCHENK, namely with regard to the outline of the chambers, is considered to be improper, as well as the new generic name. The attribution of *Labyrinthina* to the *Lituolidae* is held questionable by the writer, and the origin of the proposed genus might be better sought among the variegated family of the *Placopsilinae* (f. i. *Acruliammina* type).

The well-preserved Middle Jurassic specimen figured by R. WEYNSCHENK as *Recurvoides* cf. *trochamminiforme* HÖGLUND (WEYNSCHENK, 1951, pl. 112, figs. 1-3), clearly proves that our concept as to the first stratigraphic appearance of the genus *Recurvoides* in the Tertiary has to be abandoned.

The genus *Haurania* HENSON, 1948, supposed by its author to be derived from a lituolid stock, is classed among the *Lituolinae* auct. (HENSON, 1948, p. 8, 11). It shows an initial spiral, uncoils in the adult, displays a cribrate aperture, in other words, is externally very similar to *Lituola* LAMARCK or *Pseudocyclammina* YABE and HANZAWA. The latter genus, however, exhibits a complex alveolar hypodermis (with transverse and parallel elements) diagnostic of the *Spirocyklininae*, while *Haurania* only shows transverse partitions. In this respect, *Haurania* closely resembles certain meandropsinid genera, a similarity which has been attributed by F. R. S. HENSON to isomorphism (*loc. cit.*, p. 11). As the writer lays most weight on the interior structure, he prefers, therefore, to place *Haurania* phylogenetically near the expanded genus *Meandropsina* MUNIER-CHALMAS, 1899, emend. HENSON, 1950, which

<sup>15</sup> A publication by R. WEYNSCHENK on the occurrence of *Pseudocyclammina lituus* and this new lituolid genus in the "Vorfeld Breccia" is pending (personal communication).

also absorbs, f. i. the *Haurania*-like form *Rhapydionina* STACHE, 1912. *Haurania* may thus very well be a Jurassic forerunner of the *Meandropsinidae* HENSON and is, on this account, removed from the *Lituolidae*.

*Spirocyclina* MUNIER-CHALMAS, 1887, based on *Sp. choffati* MUNIER-CHALMAS, can hardly be differentiated in its early stage from *Choffatella* SCHLUMBERGER. Externally, *Spirocyclina* often shows a slight peripheral thickening of the test which is not observed in the discoidal compressed test of *Choffatella*. The septa of the latter genus are, moreover, generally less strongly recurved than in *Spirocyclina*; furthermore, the reticulate hypodermis of *Spirocyclina* is more complex (presence of interseptal lamellae, radial and vertical partitions).

A very characteristic morphological feature of *Spirocyclina* is the reniform-cyclical adult stage.

A discussion and emendation of the genus has been presented by MAYNC (1938), BONTE (1942), and HENSON (1948).

The original genotype, *Spirocyclina choffati* MUNIER-CHALMAS, 1887, from the Senonian of Martigues, near Marseille (France), has never been figured and its relationship with the Lower Cretaceous-Upper Jurassic species of *Spirocyclina* is still not cleared up. Most likely, the Senonian *Sp. choffati* MUNIER-CHALMAS has nothing to do with the Lower Cretaceous—Upper Jurassic species *Sp. choffati* MUNIER-CHALMAS var. *lusitanica* and var. *infravalanginiensis* (CHOFFAT), regarded by the writer as separate species: *Sp. lusitanica* (CHOFFAT) and *Sp. infravalanginiensis* (CHOFFAT) (see MAYNC, 1938, p. 63). It is even probable that the Senonian form is generically different from the Lower Cretaceous-Upper Jurassic ones generally referred to *Spirocyclina*. A thorough revision of the genus and its species, based on original and topotype material, would be highly commendable.

The genus *Yaberinella* was erected by T. W. VAUGHAN, in 1928, with *Y. jamaicensis* VAUGHAN from the Eocene of Jamaica as genoholotype (VAUGHAN, 1928, p. 7). It is an operculinoid, externally sometimes *Choffatella*-like form becoming cyclical (rarely uncoiled) in the adult, with a vertical series of apertural openings. Its internal structure presents a peculiar criss-cross (damask) pattern unknown to any other *spirocyclinine* genus: The interseptal partitive elements intersect at low angles and are not normal to the septa (as e. g. in *Spirocyclina*).

*Yaberinella* is regarded as being an over-specialized, probably dead-end offspring of the *Spirocyclininae* (MAYNC, 1949, p. 537) which has hitherto only been found with certainty in the Jamaica Eocene. Unfortunately, no specimens of this complex genus could be studied first-hand by the writer.

#### KEY TO THE LITUOLIDAE

Family *Lituolidae*: Test free, multilocular; chambers

arranged in a planispiral, rarely trochospiral or streptospiral coil; spire in adult stages often uncoiling or becoming reniform-annular; walls and septa arenaceous (with a varying amount of calcareous cement) or entirely calcareous (microgranular); interior of test simple or complex (labyrinthic); imperforate epidermal layer, sometimes underlain by a reticular-alveolar hypodermis; aperture simple or multiple.

#### I. Interior structure simple (non-labyrinthic).

A. Texture of wall varying from predominantly calcareous to coarsely arenaceous.

Subfamily *Haplophragmoidinae* n. subfam.

(1) Planispirally coiled in all stages; test more or less involute.

1) Aperture a simple horizontal slit.

a) At base of apertural face (interio-marginal) . . . *Haplophragmoides*

b) Above base of apertural face (interio-areal) . . . *Cribrostomoides*, **partim**

c) Above base of apertural face (interio-areal), divided by tooth-like processes . . . *Cribrostomoides*, **partim**

2) Aperture multiple.

a) Horizontal series of rounded connected openings (dentate) above apertural face (interio-areal) . . . *Cribrostomoides*, **partim**

(2) Planispirally coiled in early stages, later coiling in different planes (streptospiral); not uncoiling.

1) Aperture a simple slit, with lips (interio-areal) . . . *Recurvoides*

(3) Irregularly coiled throughout (planispiral, trochospiral, streptospiral).

1) Aperture simple.

a) At base of apertural face (interio-marginal) . . . *Trochamminoides*

Subfamily *Lituolinae* s. str.

(1) Planispirally coiled in early stages, uncoiling in the adult.

1) Aperture simple, terminal.

a) A rounded opening.

aa) Uncoiled portion circular or oval in section . . . *Ammobaculites*

With secondarily added wall material . . . *Ammoscalaria*

bb) Uncoiled chambers frondicularian, triangular in section . . . *Frankeina*

cc) Coiled portion lacking in megalospheric form . . . *Triplasia*

b) An elliptical opening.

aa) Uncoiling chambers rectilinear, compressed . . *Ammomarginulina* (=compressed . *Ammobaculites*)

bb) Uncoiled chambers frondicularian . . . *Flabellamina*



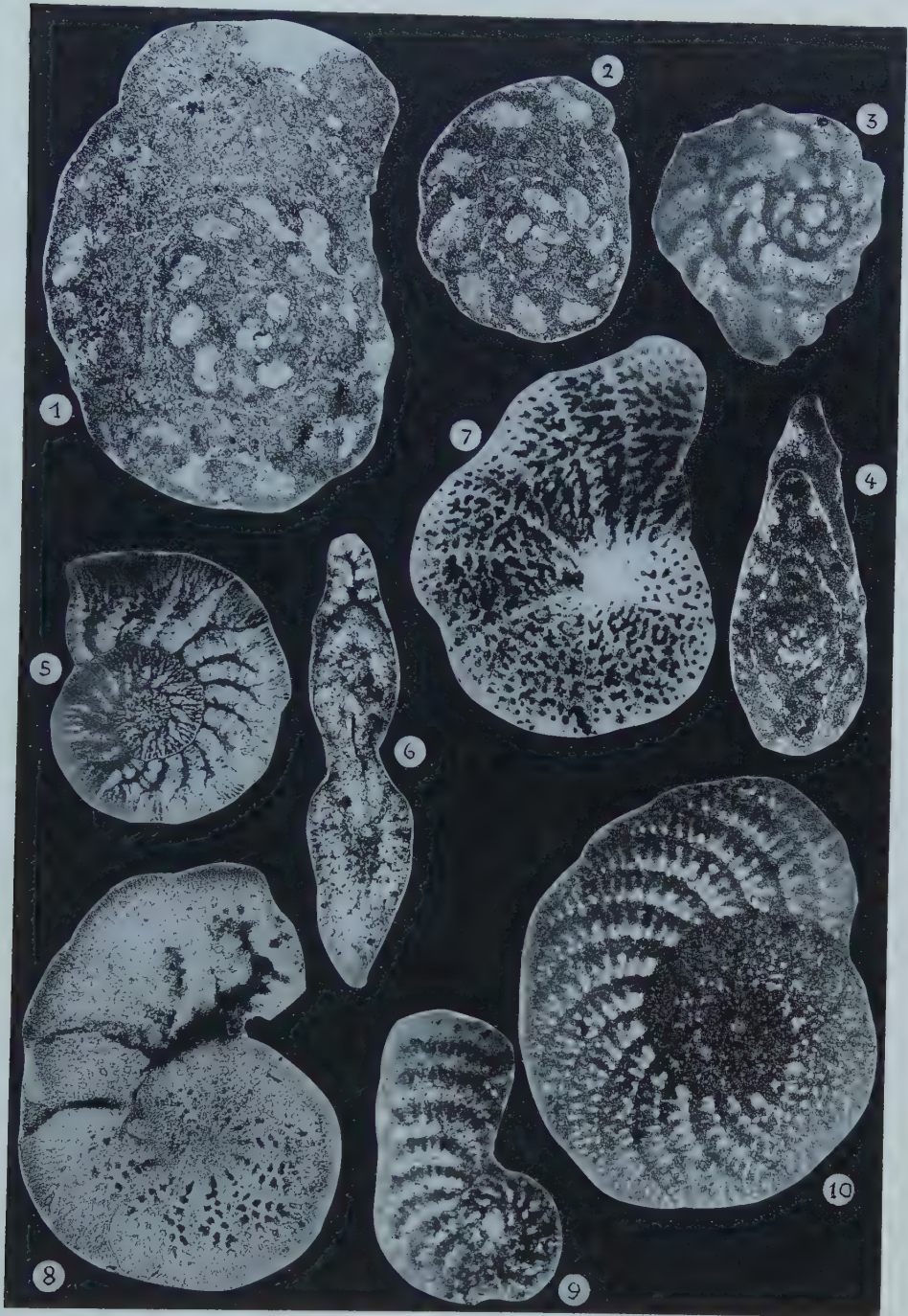
- c) An elongate opening with lateral tooth-like processes (crenulate) *Buccicrenata*
  - d) A short vertical slit at peripheral angle . . . . . *Phenacophragma*
  - 2) Aperture multiple.
    - a) A vertical series of pores on the apertural face . . . . . *Stomatostoecha*
    - b) Cribrate, terminal . . . *Lituola* emend. (= *Haplophragmium*, **olim, pro parte**)
    - c) Possibly cribrate (adult).
      - aa) Lumina peripherally filled by a spongy (alveolar) matrix . . . . . *Discamminoides*
  - (2) Initial spire streptospiral (coiling in different planes); uncoiling in the adult.
    - 1) Aperture simple . . . *Bulbobaculites* n. gen.
    - 2) Aperture multiple, cribrate . . . . . *Bulbophragmium* n. gen.
- II. Interior structure complex.
- Presence of an *alveolar hypodermis* and/or *labyrinthic interior structure* of wall and septa.
- A. Texture of wall varying from predominantly calcareous to arenaceous.
- Subfamily *Spirocyclininae*.
- (1) Planispirally coiled in all stages.
    - 1) Aperture a curved slit at base of apertural face (interio-marginal), with lip . . . . . *Alveolophragmium*
  - 2) Aperture multiple.
    - a) Cribrate with additional horizontal slit at base of apertural face (interio-marginal) . . . . . *Cyclammina*
  - (2) Planispirally coiled in early stages, uncoiling in the adult.
    - 1) Aperture multiple.
      - a) Cribrate . . . . . *Pseudocyclammina*
      - b) A vertical series of pores in a linear depression . . . . . *Choffatella*
  - (3) Planispirally coiled in early stages, reniform-annular in the adult.
    - 1) Aperture multiple.
      - a) A series of pores on the peripheral face; early stage as *Choffatella* . . . . . *Spirocyclina*
      - b) A series of pores on apertural face; interior showing a very complex criss-cross pattern . . . . . *Yaberinella*
- REFERENCES
- APPLIN, E. R., and JORDAN, L., 1945, Diagnostic foraminifera from subsurface formations in Florida. *Journ. of Pal.*, vol. 19, no. 2, pp. 129-148, Pls. 18-21, March, 1945.
- , LOEBLICH, A. R., and TAPPAN, H., 1950, Two new Lower Cretaceous lituolid Foraminifera. *Journ. Wash. Acad. Sc.*, vol. 40, no. 3, pp. 75-79, March, 1950.
- ASANO, K., 1950, Some *Lituolidae* from the Tertiary of Japan. *Contr. Cushman Found. Foram. Research*, vol. I, pts. 3 and 4, pp. 75-79, Pls. 11-12, November, 1950.
- BARTENSTEIN, H., and BRAND, E., 1949, New genera of foraminifera from the Lower Cretaceous of Germany and England. *Journ. of Pal.*, vol. 23, no. 6, pp. 669-672, November, 1949.
- BONTE, A., 1942, *Orbitammina elliptica* d'ARCH. sp., foraminifère de grande taille du Bathonien supérieur de l'Aisne et des Ardennes. *Soc. Géol. France, Bull.*, 5th ser. vol. XII, pp. 329-350, Pl. IX.
- BRADY, H. B., 1884, Report on the foraminifera dredged by H.M.S. Challenger during the years 1873-76. *Challenger Exped. Report, Zool.*, vol. 9, pt. 22, pp. 1-814, Pls. 1-115.
- BRÖNNIMANN, P., 1951a, *Guppyella*, *Alveovalvulina*, and *Discamminoides*, new genera of arenaceous foraminifera from the Miocene of Trinidad, B.W.I. *Contr. Cushman Foundation Foram. Research*, vol. II, pt. 3, October, 1951, pp. 97-105, Pl. II, text figs. 1-12.
- , 1951b, Internal structure of *Cyclammina cancellata*. *Journal of Pal.*, vol. 25, no. 6, November, 1951, pp. 756-761, text figs. 1-13.
- BÜTSCHLI, O., 1880, System der *Rhizopoda*. In: BRONN, H. G., 1880, *Klassen und Ordnungen des Thier-Reichs*. Leipzig und Heidelberg, C. F. Winter, vol. 1, Abt. I. pp. 172-217, Pls. 1-13.
- CHAPMAN, F., 1892, The Foraminifera of the Gault of Folkestone. *Journ. Royal Micr. Soc.*, 1892, pt. II, pp. 319-330, Pls. V-VI.
- , 1926, The Cretaceous and Tertiary Foraminifera of New Zealand. *New Zealand Geol. Survey, Pal. Bull.* no. 11.
- COLOM, G., 1946, Introducción al estudio de los microforaminíferos fosiles. Consejo superior de investigaciones científicas, Inst. "Lucas Mallada." Madrid, 1946.
- COX, P. T., 1937, The genus *Loftusia* in South-Western Iran. *Ecl. Geol. Helv.*, vol. 30, no. 2, pp. 431-450, Pls. XXXIII-XXXVII.
- CUSHMAN, J. A., 1910, A monograph of the foraminifera of the North Pacific Ocean. *Smithsonian Inst., U. S. Nat. Mus., Bull.* 71, pt. I, Wash.
- , 1920, The foraminifera of the Atlantic Ocean. *Smithsonian Inst., U. S. Nat. Mus., Bull.* 104, pt. II, Wash.
- , 1927a, An outline of a re-classification of the foraminifera. *Contr. Cushman Lab. Foram. Research*, vol. 3, pt. 1, pp. 1-105, Pls. 1-21, March, 1927.
- , 1927b, Some notes on the early foraminiferal genera erected before 1808. *Contr. Cushman Lab. Foram. Research*, vol. 3, pt. 2, pp. 122-126, June, 1927.
- , 1927c, Notes on the collection DEFRANCE.

- Contr. Cushman Lab. Foram. Research, vol. 3, pt. 3, pp. 141-145, Pl. 28, September, 1927.
- , 1928, Additional genera of the Foraminifera. Contr. Cushman Lab. Foram. Research, vol. 4, pt. 1, pp. 1-8, Pl. 1.
- , 1948, Foraminifera, their classification and economic use. 4th ed., Cambridge, Mass., Harvard Univ. Press.
- and JARVIS, P. W., 1928, Cretaceous foraminifera from Trinidad. Contr. Cushman Lab. Foram. Research, vol. 4, pt. 4, pp. 85-103, Pls. 12-14, December, 1928.
- and ALEXANDER, C. I., 1929, *Frankeina*, a new genus of arenaceous foraminifera. Contr. Cushman Lab. Foram. Research, vol. 5, pt. 3, pp. 61-62, September, 1929.
- and WATERS, J. A., 1929, Some arenaceous foraminifera from the Taylor marl of Texas. Contr. Cushman Lab. Foram. Research, vol. 5, pt. 3, pp. 63-66, September, 1929.
- and HEDBERG, H. D., 1941, Upper Cretaceous foraminifera from Santander del Norte, Colombia, S.A. Contr. Cushman Lab. Foram. Research, vol. 17, pt. 4, pp. 79-100, Pls. 21-23, December, 1941.
- and GOUDKOFF, P. P., 1944, Some Foraminifera from the Upper Cretaceous of California. Contr. Cushman Lab. Foram. Research, vol. 20, pt. 3, pp. 54-64, Pls. 9-10, September, 1944.
- and RENZ, H. H., 1946, The foraminiferal fauna of the Lizard Springs formation of Trinidad, British West Indies. Contr. Cushman Lab. Foram. Research, Special Publ. no. 18, pp. 1-48, Pls. 1-8.
- and GLAZEWSKI, K., 1949, Upper Jurassic foraminifera from the Nizniow limestone of Podole, Poland. Contr. Cushman Lab. Foram. Research, vol. 25, pt. 1, pp. 1-11, Pls. 1-2, March, 1949.
- CUVILLIER, J. and SZAKALL, V., 1949, Foraminifères d'Aquitaine. Soc. Nat. des Pétroles d'Aquitaine, pt. 1, Toulouse, pp. 1-112, Pls. 1-32.
- DAM TEN, A., 1946, Arenaceous foraminifera and *Lagenidae* from the Neocomian (Lower Cretaceous) of The Netherlands. Journ. of Pal., vol. 20, no. 6, pp. 570-577, Pls. 87-88, November, 1946.
- ELLIS, B. F., and MESSINA, A. R., 1940 etc., Catalogue of Foraminifera. Special Publication, The American Mus. of Nat. Hist., New York.
- FRANKE, A., 1927, Die Foraminiferen der Aachener Kreide. Jahrb. Preuss. Geol. Landesanst., 1927, vol. XLVIII (1928), pp. 667-698.
- , 1928, Die Foraminiferen der Oberen Kreide Nord- und Mitteldeutschlands. Abhandl. Preuss. Geol. Landesanst., Berlin, 1928, N. F., Heft 111, pp. 1-207, Pls. I-XVIII.
- FRIZZELL, DON L., and SCHWARTZ, E., 1950, A new Lituoloid foraminiferal genus from the Cretaceous, with an Emendation of *Cribrostomoides* CUSHMAN. School of Mines and Met., Bull. Rolla, Miss. Techn. ser., No. 76, pp. 1-12, Pl. 1, Sept., 1950.
- GALLOWAY, J. J., 1933, A Manual of Foraminifera. James Furman Kemp Memorial Series, Publ. no. 1, Bloomington, Ind.
- GERMERAAD, J. H., 1946, Geology of Central Seran. In: Geological, Petrographical and Palaeontological results of explorations, carried out from September 1917 till June 1919 in the Island of Ceram, by L. RUTTEN and W. HOTZ. 3d ser., no. 2, de Bussy, Amsterdam.
- GLAESSNER, M. F., 1947, Principles of Micropalaeontology. John Wiley and Sons, New York.
- GOËS, A., 1896, Reports on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf

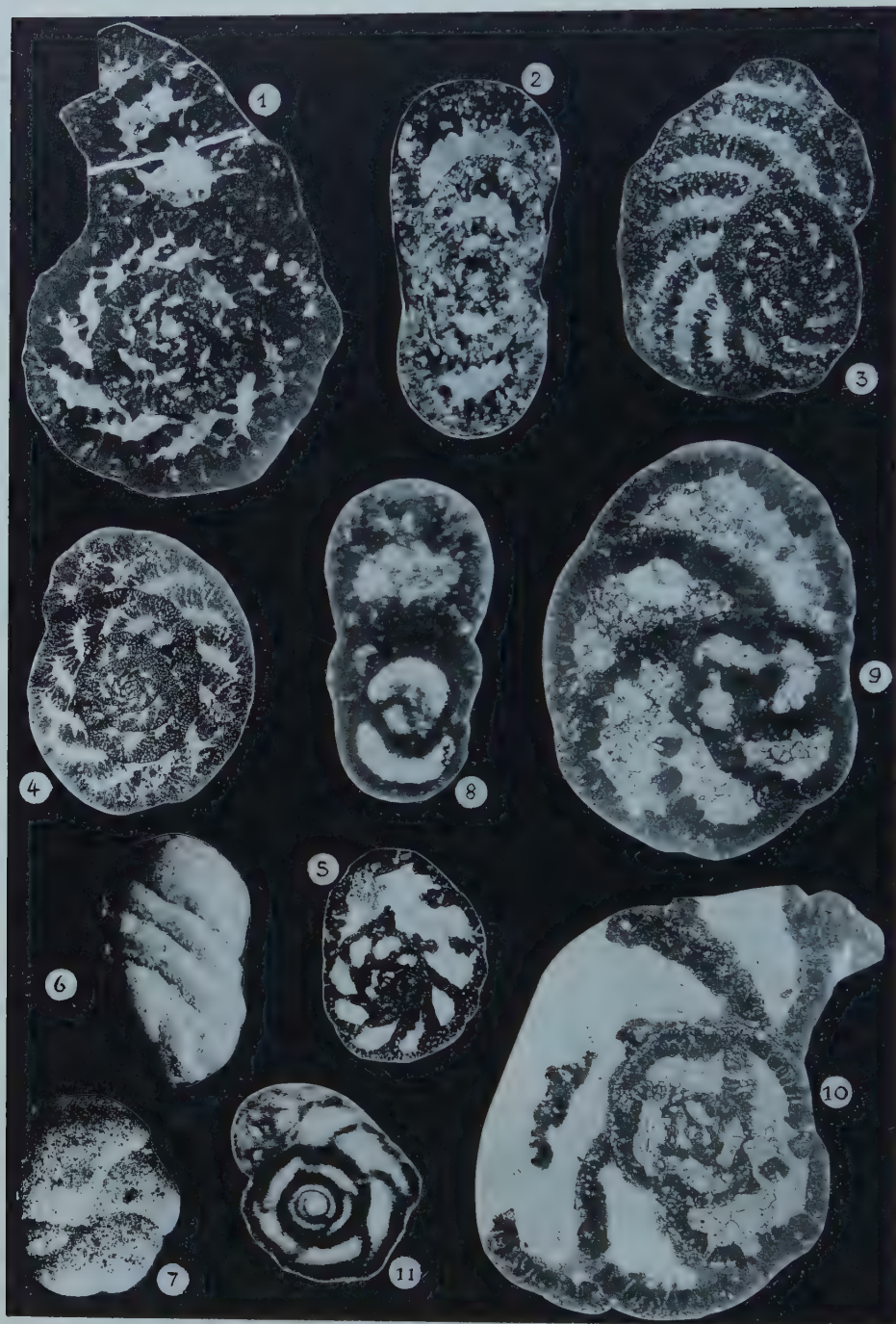
## EXPLANATION OF PLATE 11

FIGS.		PAGE
1-2.	<i>Lituola taylorensis</i> Cushman and Waters. Topotype specimens (Taylor marl Marquez Dom, Leon Cty., Texas, USA).	
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9-10.	<i>Choffatella decipiens</i> Schlumberger.	
	9. Hauterivian Cretaceous Djebel Tideft near Baudens, Oran, West Algeria. Median section of a small specimen revealing a large uncoiled portion, $\times 47$ .	50
	10. Lower Cogollo formation (Aptian), Quebrada San Pedro, Lara, Western Venezuela. Shallow median section disclosing reticulate hypodermis. Note the regular septa and delicate interior structure, $\times 47$ .	50





Maync, Lituolidae



Maync, Lituolidae



- of California, in charge of A. Agassiz, carried on by the U. S. Fish Commission Steamer "Albatross" during 1891. Part XX. The foraminifera. Harvard Coll., Mus. Comp. Zool., Bull., Cambridge, Mass., vol. 29.
- HANZAWA, SH., 1947, Notes on some species of *Pseudocyclammina* from Sumatra. Japanese Journ. of Geol. and Geogr., vol. XX, nos. 2-4, pp. 5-8, Pl. IV.
- HENBEST, L. G., 1931, The species *Endothyra baileyi* (HALL). Contr. Cushman Lab. Foram. Research, vol. 7, pt. 4, pp. 90-93, Pl. 12, December, 1931.
- HENSON, F. R. S., 1947, New *Trochamminidae* and *Verneulinidae* from the Middle East. Annals and Magaz. Nat. Hist., ser. 11, vol. XIV, pp. 605-630, Pls. XIV-XVIII, September, 1947 (published June, 1948).
- , 1948, Larger Imperforate Foraminifera of South-Western Asia. British Museum Nat. Hist., London, 1948, pp. 1-127, Pls. I-XVI.
- , 1950, Middle Eastern Tertiary *Peneroplidae* (Foraminifera), with remarks on the phylogeny and taxonomy of the family. The West Yorkshire Printing Co., Wakefield, Engl., pp. 1-70, Pls. 1-10.
- HOFKER, J., 1949, On Foraminifera from the Upper Senonian of South Limburg (Maestrichtian). Inst. Royal Sc. Nat. de Belgique, Mém. no. 112, Bruxelles, pp. 1-69, Figs. 1-23.
- HÖGLUND, H., 1947, Foraminifera in the Gullmar Fjord and the Skagerrak. Zoologiska Bidrag Uppsala, vol. 26, pp. 1-328, Pls. 1-32.
- JONES, T. R., 1884, Notes on the foraminifera and ostracoda from the deep boring at Richmond. Geol. Soc. London, Quart. Journ., 1884, vol. 40, pp. 765-777, Pl. 34.
- KARRER, F., 1865, Über das Auftreten von Foraminif-  
eren in den älteren Schichten des Wiener Sandsteins. K. Akad. Wiss., Math.-Naturw. Cl., Sitzber. Wien, vol. 52, Abt. 1, no. 9, pp. 492-497.
- KOECHLIN, E., 1942, *Pseudocyclammina virguliana* n. sp. aus den Virgula-Mergeln des Berner Jura. Ecl. Geol. Helv., vol. 35, no. 2, pp. 195-199, Pl. VI.
- LAMARCK, J. B. P. A. M., 1804, Sur les Fossiles des environs de Paris. Annales du Muséum National d'Histoire Naturelle, vol. V, pp. 242-245, Pl. XIV.
- LOEBLICH, A. R., and TAPPAN, H., 1949, Foraminifera from the Walnut formation (Lower Cretaceous) of northern Texas and southern Oklahoma. Journ. of Pal., vol. 23, no. 3, pp. 245-266, Pls. 46-51, May, 1949.
- MARIE, P., 1941, Les Foraminifères de la Craie à *Bellinitella mucronata* du Bassin de Paris. Mém. Muséum National d'Histoire Naturelle, nouv. sér., vol. XII, Fasc. 1, Paris, pp. 1-296, Pls. I-XXXVII.
- MAYNC, W., 1938, Die Grenzschichten von Jura und Kreide in der Titliskette. Ecl. Geol. Helv., vol. 31, no. 1, pp. 21-70, Pls. I-IV.
- , 1949, The foraminiferal genus *Choffatella* SCHLUMBERGER in the Lower Cretaceous of the Caribbean Region (Venezuela, Cuba, Mexico, and Florida). Ecl. Geol. Helv., vol. 42, no. 2, pp. 529-547, Pls. XI-XII.
- MUNIER-CHALMAS, M., 1887, Sur trois genres nouveaux de Foraminifères. Compte rendu sommaire, Soc. Géol. France, 1886-1887, pp. XXX-XXXI, 21 février, 1887.
- , 1902, Sur les Foraminifères ayant un réseau de mailles polygonales. Soc. Géol. France, Bull., (4), tome II, pp. 349-351, 16 juin, 1902.
- ORBIGNY D', A. D., 1840, Mémoire sur les Foraminifères de la Craie Blanche du Bassin de Paris. Mém. Soc. Géol. France, vol. 4, pt. 1, pp. 1-51, Pls. I-IV.

## EXPLANATION OF PLATE 12

FIGS.	PAGE
1-2. <i>Pseudocyclammina lituus</i> (Yokoyama). Torinosu limetstone, Noguchi, Ogawa-Mura, Kochi Prefecture, Japan.	
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2. Axial section through spire, displaying labyrinthic wall structure and broadly rounded periphery, $\times 18$ .	50
3. <i>Pseudocyclammina personata</i> Tobler. Kimmeridgian Jurassic ( <i>Pseudocidaris thurmanni</i> beds), Delémont, Bernese Jura Mts., Switzerland. Median section showing regular <i>Choffatella</i> -like features, $\times 18$ .	50
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6-10. <i>Pseudocyclammina rugosa</i> (d'Orb.). Cenomanian Ile Madame, Charente (France).	
6. Uncoiling specimen, $\times 11$ .	50
7. Coiled portion of a specimen, $\times 10$ .	50
8. Axial section showing labyrinthic wall structure and broadly rounded periphery, $\times 24$ .	36
9. Median section revealing the labyrinthic structure of the wall, $\times 18$ .	36
10. Median section displaying the labyrinthic (spongy) wall structure, $\times 18$ .	36
11. <i>Lituola watersi</i> (Cushman and Waters). Eocene Avon Park limestone, Florida, USA. Median section showing the simple compact wall structure, $\times 30$ .	46

- PARR, W. J., 1935, Some foraminifera from the Awamoa of the Medway River District, Awatere, Marlborough, New Zealand. Royal Acad. Soc. New Zealand, Trans. Proc., Dunedin, New Zealand, vol. 65.
- PFENDER, J., 1938, Les Foraminifères du Valanginien Provençal. Soc. Géol. France, Bull., sér. 5, vol. VIII, pp. 231-242, Pls. XIII XVI.
- REICHEL, M., 1936, Études sur les *Alvéolines*. Abhandl. Schweiz. Pal. Ges., vol. LVII, pp. 1-93, Pls. 1-9.
- REUSS, A. E., 1854, Beiträge zur Charakteristik der Kreideschichten in den Ostalpen, besonders im Gosauthale und am Wolfgangsee. Denkschr. K. Akad. Wiss. Wien, vol. 7, 1854, pp. 65-72, Pls. XXV-XXVIII.
- , 1860, Die Foraminiferen der Westphälischen Kreideformation. Sitz. ber. K. Akad. Wiss. Wien, Math.-Naturw. Cl., vol. 40, pp. 147-238, Pls. I-XIII.
- , 1862, Entwurf einer systematischen Zusammenstellung der Foraminiferen. K. Akad. Wiss. Wien, Math.-Naturw. Cl., vol. 44 (Jahrg. 1861) Abth. 1.
- SCHLUMBERGER, CH., 1904, Note sur le genre *Choffatella* n. g. Soc. Géol. France, Bull., sér. 4, vol. IV, no. 6, pp. 763-764, Pl. XVIII.
- and CHOFFAT, P., 1904, Note sur le genre *Spirocyclina* MUNIER-CHALMAS et quelques autres genres du même auteur. Soc. Géol. France, Bull., sér. 4, vol. IV, no. 3, pp. 358-368, Pls. IX-X.
- SHIMER, H. W., and SHROCK, R. R., 1944, Index Fossils of North America. John Wiley & Sons, New York.
- SILVESTRI, A., 1925, Sur quelques foraminifères et pseudoforaminifères de Sumatra. Beiträge z. Geol. und Pal. von Sumatra, Verhand. Geol.-Mijnbouwk. Genootschap voor Nederland en Kolonien, Geol. Ser., pt. VIII, pp. 449-460, Pls. I-III.
- , 1932, Revisione di Foraminiferi Preterziarii del Sud-Ovest di Sumatra. Revista Italiana di Paleontologia, vol. XXXVIII, fasc. iii-iv, pp. 75-107, Pls. II-IV.
- STSCHEDRINA, Z., 1936, *Alveolophragmium orbiculatum* nov. gen. nov. sp. (Eine sandschalige Foraminifere aus dem Japanischen, Ochotskischen und Karischen Meer). Zool. Anzeiger, Leipzig, vol. 114, pp. 312-319.
- TOBLER, A., 1925, Über *Cyclammina* (*Choffatella*) *sequana* MERIAN sp. Ecl. Geol. Helv., vol. 19, no. 3, March, 1926, pp. 714-719, Pl. XXVII.
- , 1928, Über *Pseudocyclammina* und *Choffatella* im Schweizerischen Jura. Ecl. Geol. Helv., vol. 21, no. 1, 1928, pp. 212-216, Pl. XXIV.
- VAUGHAN, T. W., 1928, *Yaberinella jamaicensis*, a new genus and species of arenaceous foraminifera. Journ. of Pal., vol. 2, no. 1, March, 1928, pp. 7-12, Pls. 4-5.
- WEYNSCHENK, R., 1950, Die Jura-Mikrofauna und -flora des Sonnwendgebirges (Tirol). Schlern-Schriften, no. 83, Innsbruck, pp. 1-32, Pls. I-III.
- , 1951, Two new foraminifera from the Dogger and Upper Triassic of the Sonnwend Mountains of Tyrol. Journal of Pal., vol. 25, no. 6, November, 1951, pp. 793-795, Pl. 112, text figs. 1-3.
- YABE, H., and HANZAWA, SH., 1926, *Choffatella* SCHLUMBERGER, and *Pseudocyclammina*, a new genus of arenaceous foraminifera. Science Reports Tôhoku Imp. Univ., Sendai, Japan, 2nd ser. (Geol.), vol. IX, no. 1, pp. 9-11, Pl. II.
- YOKOYAMA, M., 1890, Foraminiferen aus dem Kalksteine von Torinosu und Kompira. In: NAUMANN, E., and NEUMAYR, M., 1890, Geologie und Paläontologie von Japan. Denkschr. kais. Akad. Wiss., Math.-Naturw. Cl., vol. LVII, Wien, pp. 26-27, Pl. V.
- ZITTEL, VON K., 1924, Grundzüge der Paläontologie. I. Abteilung: Invertebrata. 6th edition. München and Berlin, 1924.

## 57. TECHNIQUES FOR RECOGNITION OF LIVING FORAMINIFERA\*

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### SUMMARY

1. Quantitative studies of the distribution of living populations are of importance in ecologic studies and paleoecologic interpretations. Living Foraminifera have been recognized by chemical tests for proteins and by selective biologic stains.

2. Chemical color tests for protein which have been used are the BIURET reagent and MILLON's reagent. Millon's reagent can be used only with Foraminifera having

arenaceous tests. Chemical color tests are satisfactory but are difficult to use and give temporary coloration.

3. RHUMBLER'S staining technique, using methyl green-eosin, is complex to use and stains inorganic as well as organic materials in sediment samples.

4. Rose Bengal is a selective stain for protoplasm and gives positive results. It is recommended as the most reliable and efficient stain for recognizing living Foraminifera.

### INTRODUCTION

Recent intensive work on Foraminifera ecology has emphasized the need for knowledge of living popula-

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tions. Until recently, little information was available and little work was being done on distribution of living Foraminifera.

It is desirable at the present state of our knowledge to obtain quantitative information on the relationship between the distribution of living and dead populations. Previous studies have indicated that these populations are comparable in certain areas but substantiating data from other areas are desirable (PHLEGER, 1951; 1952). Such determinations would test the basic assumption underlying previous ecologic studies, that quantitative counts of Foraminifera in dried samples are accurate representations of living foraminiferal faunas. There is no information on the seasonal variation of living populations. When this information becomes available it will be possible to obtain definite quantitative information on the rate of addition of empty tests to the sediments. These data may be used as possible indicators of rates of production and sedimentation.

The study of living populations will give insight into the problem of living communities versus aggregates of skeletal remains deposited by physical agencies. If we are to study fossil faunas in the light of modern associations, it is necessary to have some knowledge of the relative importance of these two assemblages. Certain fossil associations may be the result of a natural community or may be merely accumulations of skeletal remains deposited far from their source. The interpretation of fossil strata in the light of ecology requires a knowledge of recently productive areas in relation to unproductive areas as determined by living populations and skeletal remains. It is believed that distribution studies of living Foraminifera are important tools in increasing our knowledge of ecologic and paleo-ecologic relationships.

Prior to 1946, there were few sediment samples available and few samples being collected that were suitable for analysis of living Foraminifera. With the advent of new sampling techniques, numerous carefully collected and preserved samples have become available. This store of samples, and those presently being collected, present ample opportunity for comparative studies of living populations. The purposes of the present report are 1) to describe the methods previously used to identify living Foraminifera; 2) to describe a new method using rose Bengal; and 3) to discuss and evaluate the methods in terms of their sensitivity, accuracy, selectivity, and ease of operation.

#### ACKNOWLEDGMENTS

The writer is grateful to H. J. Conn of the Biological Stain Commission for suggesting rose Bengal as a stain for Foraminifera. D. L. Fox, M. W. Johnson and Fred B. Phleger have made numerous suggestions, and Zach M. Arnold of the University of California and

members of the Scripps Institution of Oceanography have provided materials and suggestions.

#### DESCRIPTION OF METHODS

The methods which have been used to differentiate living Foraminifera from empty tests are of two general types. One type utilizes the color reactions for protein and the other involves a combination of biological stains. The methods will be treated here separately since each is subject to different qualifications.

##### COLOR REACTIONS FOR PROTEIN

Two methods have been used which are based on the color reactions between chemical reagents and one or more of the constituent radicals or groups in the complex protein molecule. Each of the processes utilizes the presence of a different group of constituent radicals in the protein molecule and gives different color reactions.

*Millon's Reagent.* MILLON's reagent is prepared as follows: Digest one part (by weight) of mercury with two parts (by weight) of nitric acid (sp. gr. 1.42) and dilute the resulting solution with two volumes of water. The precipitate which forms is allowed to settle out and the supernatant liquid is used (HAWK and BERGEIM, 1937, p. 147). The supernatant liquid is a solution of mercuric nitrate in nitric acid containing some nitrous acid. The solution imparts a red color to proteinaceous material in the presence of heat. This reaction was adapted for use on arenaceous Foraminifera in sediment samples by PHLEGER (1952). "The sediment was washed over a brass sieve having openings of 0.074 mm. The washed material was placed in a Petri dish with additional tap water. . . Several drops of MILLON's reagent were added to the solution and the sample was warmed 4 to 6 hours by the heat of a 75-watt incandescent lamp in a desk stand" (op. cit., p. 322). Care should be taken to remove all inorganic salts from the sample before the reagent is added, since, in the presence of such contaminants, the mercury in the reagent will be precipitated and the solution rendered inert. The red color reaction is due to the presence of the hydroxyphenyl group ( $C_6H_4OH$ ) in the protein molecule.

*Biuret Reaction.* The BIURET reagents include sodium hydroxide and copper sulphate. The procedure is as follows: To a washed sample in an aqueous solution an equal volume of 10% sodium hydroxide is added. The preparation is mixed thoroughly and a 0.5% solution of copper sulphate is added drop by drop with constant agitation until a blue solution is produced. Care should be taken not to add an excess of copper sulphate, which may cause a blue precipitate of copper hydroxide. In approximately 20 to 30 minutes a blue to pink color is obtained on any proteinaceous material present. The coloration is due to the reaction between the reagents in solution and two or

more linked peptide groups (-CONH-). If it is desirable to preserve the specimens for future examination, the sample should be washed free of the reagents, since otherwise the sodium hydroxide will eventually hydrolyze the protein and other organic substances which are present in the tests of many species.

A stable BIURET solution may be made as follows: Prepare a 10% solution of potassium hydroxide by dissolving 100 pellets of potassium hydroxide in  $\frac{3}{4}$  liter of distilled water. Dissolve 0.75 grams of copper sulphate in a small amount of water and add slowly with constant agitation to the hydroxide solution. If necessary, cool the hydroxide solution in a water bath before adding the copper sulphate. The resulting solution will be a dark blue and may be kept indefinitely without deterioration. This solution may be added directly to the washed sample with the same coloration of the protein.

It should be emphasized that if either of the above methods is to be employed, the original sample should be carefully washed free of sea water and fixative before addition of the reagents. In both reagents the alkali forms precipitate with magnesium salts and these interfere with the identification of proteinaceous material. It is necessary that samples to be used for the identification of living specimens be preserved in neutralized formaldehyde or alcohol as soon as possible after collection and before washing. Washing of the sample in fresh water before fixation will cause rupture of the protoplasm and consequent disaggregation. The addition of a fixative serves not only to preserve the protoplasm but to coagulate and harden it, thus presenting a concentrated mass of protein for the action of the above reagents.

#### BIOLOGICAL STAINS

In biological stains there is adsorption of the stain particles on the substance being stained; a reaction between reagents and the protein molecules is not involved. As pointed out by CONN (1946, p. 9), biological stains are simply dyes that are adapted for special purposes.

*Methyl green-eosin.* Only one method is known to the writer in which biological stains previously have been used to differentiate between living and dead Foraminifera in sediment samples. This is the method employed by RHUMBLER (1935, p. 145) using an alcohol solution of methyl green and eosin. The solution is prepared as follows: Mix 50 cc. of a 1% aqueous solution of methyl green, 50 cc. of a solution of 0.8 grams of eosin in a 50% solution of alcohol and 50 cc. of absolute alcohol. The solution should be mixed well before using. Regardless of fixative used when the sample was collected, it is first treated with water or a weak alcohol solution (not over 50%). It is then placed in the stain solution for  $\frac{1}{2}$  to  $\frac{3}{4}$  hours. Rhumbler reports that the methyl green-eosin solution,

which he has shortened to "Methgreosin," differentially stains detrital material, fecal material, and organic material. The fecal and detrital material are stained green and the organic material is stained red. It is presumed that this reference to "organic material" includes only material which was living at the time of collection. He further preserves his material by washing it in alcohol solutions of increasing concentration (70%, 95%, 100%). The material may then be kept permanently by placing it in clove oil or mounting in Canada balsam.

*Rose Bengal.* The rose Bengal method was developed as a result of this study and is presently being used by the writer in the differentiation of living and dead Foraminifera. An aqueous solution of rose Bengal is prepared by dissolving approximately 1 gram of rose Bengal in 1 liter of distilled water. The concentration of the stain solution is not critical since it only alters the intensity and not the effectiveness of the stain. The procedure being used at present is relatively simple and adds only one operation to the preparation of a sample for examination. The sediment sample is first washed in a specially designed sieve shaped like an elongated tea strainer and made of stainless steel screening that has an average opening of 0.074 mm. This process washes the sample free of sea water, fixative, and the fine silt and clay size sediment particles. The sample in the sieve is immersed in the stain solution for approximately 10 minutes. The sieve containing the sample is then removed from the stain solution, is rewashed to remove excess stain, and is transferred from the sieve to a counting tray. Rose Bengal imparts a deep rose color to the foraminiferal protoplasm. The specifications of the stain are as follows: Rose Bengal, C.I. 779;  $C_{20}H_2O_5T_4Cl_4Na_2$ ; solubility in water, 36.25%; solubility in alcohol, 7.53%. Rose Bengal has been used in the past primarily in staining bacteria, and as a cytoplasmic stain (CONN, 1946, p. 165-166).

#### DISCUSSION

The only completely accurate method of determining the true state of foraminiferal protoplasm is by observation of pseudopodial action or cytological sectioning and staining of the nuclei. Neither of these methods appears to be adaptable to ecological studies for geological and oceanographic purposes, owing to the specialized equipment and techniques required in such procedures and the large amount of material that must be examined in the course of an ecological study. The methods used in the past to differentiate between living and dead Foraminifera and the one presently being used are attempts to approximate living populations, and the results obtained are conditioned by certain basic assumptions.

#### COLOR REACTIONS FOR PROTEIN

In concluding that a protein color reaction is a positive indication of a living organism, it must first be



assumed that: 1) the color reaction is reliable, 2) the presence of protein within the shell is a positive indication of the presence of protoplasm, and 3) the presence of protoplasm is positive indication of a living or very recently dead organism. The color reactions for protein as described above are standard procedures used in physiological chemistry for protein tests and have been adapted for this particular problem. If the tests are carefully conducted there is no reason to doubt their accuracy as indicators of protein, and it appears certain that the presence of native protein does indicate the presence of protoplasm. It is generally accepted that foraminiferal protoplasm is amoeboid in structure and contains the constituent radicals to which the color reactions are sensitive. HAWK and BERGEIM (1937, p. 147) point out that "various substances not proteins respond to certain of these color reactions." These "substances" will not be considered here, but the probability of their occurrence in Foraminifera shells is negligible.

The third assumption involves the rate of decay of organic material, including protoplasm, in the ocean. The life cycle of the Foraminifera does not involve natural death of mature specimens. Continuous growth and sexual and asexual reproduction in these Protozoa are infinite processes, barring the interference of external agents of death. If the animals are eaten by other animals, which is certainly the fate of many Foraminifera, the protoplasm would disintegrate on contact with intestinal fluids. If we assume, however, that the animals are killed *in situ* by some radical change in physical environment, what would be the fate of the protoplasm? Considerable work on the rate of decay of organic material in marine sediments has shown that bacterial decomposition of such protoplasm is extremely rapid, the material remaining as recognizable protoplasm for a very brief period. (ZOBELL, 1948, p. 138, 143). Even if it is assumed that a small proportion of the Foraminifera which reacted positively to color tests are recently dead (within a few days) they may be enumerated among the living specimens.

The usefulness of the protein tests and the degree of coloration varies. MILLON's reagent contains free nitric acid and is limited in its use to arenaceous faunas. It has been used in the past (PHLEGER, 1952) on sediment samples after a preliminary examination to check for calcareous specimens. The samples on which the MILLON's reagent was used contained very few calcareous specimens and these were counted before the addition of the reagent. The red color obtained in this test is definite but breakage of most of the arenaceous specimens was required for identification of protein. The principal disadvantage of the MILLON's reaction is its restricted usefulness.

The BIURET reaction has been used more extensively in this country than any of the other methods. It has

been used with considerable success on both planktonic and benthonic Foraminifera (PHLEGER, 1945, 1951). The primary objection to the use of the BIURET reaction is the relatively weak and temporary nature of the coloration. At maximum coloration, the color varies from blue to pink and frequently the tests must be broken to detect the protein; the permanency of the color varies with the concentration of the hydroxide in the BIURET solution. In recent observations, using a stable BIURET solution, maximum coloration was obtained in approximately 20 to 30 minutes with complete decoloration in from 1 to 2 hours after the solution had been added to the sample. In previous experiments, however, the color remained from 4 to 6 hours. The BIURET reagent can be used on both calcareous and arenaceous forms.

#### THE STAIN TESTS

The use of a biological stain often requires the knowledge of special techniques and equipment, but only because of the complexity of the substances being stained, not because of the complexity of the staining process. The theory of staining is the same as that of any common dyeing process. The stain selected for any particular use is done so experimentally, according to the coloration desired and the affinity of the stain for the structure or substance under consideration. By virtue of this characteristic of stains, the assumption underlying their use as diagnostic indicators of living Foraminifera is that stain has an affinity for protoplasm. It is assumed that the presence of protoplasm indicates that the specimen was alive when collected or only recently dead, as discussed above. The substances that have been observed to occur on or in both living Foraminifera and empty tests are as follows: calcite, silica, "chitin," iron oxide, detrital minerals, organic and inorganic debris, algae, and foraminiferal protoplasm. The accuracy of the assumption will be determined by the selectivity of the stain for protoplasm.

RHUMBLER's technique is not satisfactory for rapid identification of living Foraminifera in sediment samples. The "Methgreosin" solution stains everything in a sediment sample, including "chitin," fecal material, and detritus (RHUMBLER, 1935, p. 145). Although the sediment and living animals are differentiated colorimetrically in the staining process, it is undesirable to have all the material stained. In ecological studies for geological purposes the animals, living or dead, must be regarded as constituents of the sediment sample. The information obtained from quantitative studies of living Foraminifera must be considered collaterally with other sediment characteristics; the emphasis is not on the living animal alone but on the living animal in association with the other sediment characteristics. A stain solution which obscures or alters the sediment characteristics is not desirable for ecological studies even though it distinguishes between living animals and empty tests.

Many stains are available which could be used to stain isolated specimens of living or preserved Foraminifera. One of the purposes of this study has been to find a stain which could be applied to living Foraminifera in a washed sediment sample without incidental staining of organic or inorganic debris. Many stains and combinations of stains were tried, none of which was satisfactory, because of their nonselective action.

At the suggestion of H. J. CONN of the Biological Stain Commission, the higher homologs of eosin (phloxine, erythrosin, and rose Bengal) were tried. Rose Bengal was found to fulfill more closely the specifications of a foraminiferal stain than any other. A series of experiments involving various concentrations of the stain in aqueous solution were conducted on preserved samples from the Gulf of Mexico, the coast of California, and freshly collected samples from the La Jolla, Calif., area. Rose Bengal stained only organisms which were living at the time of collection. Worms, arthropods, and Foraminifera shells containing protoplasm were stained a deep rose, leaving empty shells, organic and inorganic debris unstained. Several specimens of copepods and hydroids were stained with rose Bengal to determine the effect of this stain on "chitin." It was found to impart a pink tint to "chitin" but this color is in contrast to the deep rose color obtained on living protoplasm, hence no difficulty is encountered in distinguishing the two degrees of coloration. The color of the stained protoplasm can be clearly seen through the arenaceous tests of such species as *Arenoparrella mexicana* (KORNFELD), *Miliammina fusca* (H. B. BRADY), and *Trochammina inflata* (MONTAGU) in wet samples, and is plainly visible through the walls of calcareous specimens.

It is believed that enumeration of living animals with the use of rose Bengal is within the accuracy of known sampling and counting techniques. Many inherent errors are present in any population count: it is generally assumed, perhaps erroneously, that a given

sample is representative of a given area many times its diameter; the condition of the protoplasm of the living animal at the time of collection may vary; various states of maturity and reproduction must be present in a given sample, and these stages may give different stain characteristics; a personal counting and identification error is also inherent in population counts.

It is apparent that we need not seek greater accuracy in determinations of living specimens as long as our results are conditioned by the above variables. Attempts are presently being made to increase the accuracy of population counts and to define and limit the variables indicated above.

#### REFERENCES

- CONN, H. J. (1946) Biological stains, W. F. Humphrey Press Inc., Geneva, N. Y.
- HAWK and BERGEIM (1937) Practical physiological chemistry, P. Blakistons Son and Co. Inc., Philadelphia, Pa.
- LEE, ARTHUR BOLLES (1937) The microtomists vademecum, P. Blakistons Son and Co. Inc., Philadelphia, Pa.
- PHLEGER, F. B (1945) Vertical distribution of Pelagic Foraminifera, *Amer. Jour. Science*, Vol. 243, July, 1945, p. 377-383.
- (1951) Ecology of Foraminifera, northwest Gulf of Mexico, Pt. 1, Foraminifera Distribution, *Geol. Soc. Amer. Mem.* 46, p. 1-88.
- (1952) Foraminifera ecology off Portsmouth, New Hampshire, *Bull. Mus. Comp. Zool. Harvard*, vol. 106, No. 8, pp. 315-390.
- RHÜMBLER, L. (1935) Rhizopoden der Kieler Bucht, gesammelt durch R. Remane I Teil; *Schriften Naturwiss. Verein f. Schleswig-Holstein Bd. XXI*, H2, p. 143-195.
- ZOBELL, CLAUDE (1946) Marine microbiology, Chronica Botanica Company.

## 58. REVISION OF THE TUBULAR MONOTHALAMIA

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**ABSTRACT**—Reasons and principles for a rearrangement of tubular *Monothalamia* are given and a new classification is proposed. The corresponding forms are arranged in six subfamilies (*Amphitreminae*, *Argillotubinae*, *Psammisiphoninellinae*, *Micatubinae*, *Bathysiphoninae*, *Testulosiphoninae*) and eight new genera (*Argillotuba*, *Millettina*, *Psammisiphonella*, *Oculosiphon*, *Globosiphon*, *Micatuba*, *Testulosiphon* and *Testulorhiza*) are erected.

### I. INTRODUCTION

The study of the diagnoses and the figures of various species assigned to *Bathysiphon* has revealed a great discrepancy among them. It leads to a conclusion that

only relatively few of them were determined in strict accordance with the original definition. Because of their simple, primitive, generally tubular shape the identification is often doubtful and therefore the genus as a whole cannot be well founded without considering not only the morphological characters of the test but also the important details of the wall-texture. This is particularly true in regard to the taxonomic position of the fossil species which are often based on fragmentary preservation.

A similar situation prevails in most of the *Mono-*



*thalamia* as a whole. In the present paper the genus *Bathysiphon*, being one of the most important and most common representatives of tubular *Monothalamia*, was chosen as a basis for discussion of their taxonomic relationship.

L. DE FOLIN (1896) quotes the long description of the genus *Bathysiphon* by G. O. SARS, based on the original diagnosis formulated by his father, M. SARS. CUSHMAN (1950, p. 73) gives the following description of the genus: "Test free, cylindrical, often tapering slightly, straight or slightly curved, sometimes constricted externally; wall with a base of broken sponge-spicules firmly cemented and overlaid with fine-grained, amorphous material, soft or firmly cemented, often with a very thin surface coating; apertures at the ends of the tube." In one of his earlier works, "Foraminifera of the Atlantic Ocean," part I: *Astrorhizidae* (1918), p. 27, Cushman emphasizes that the test is "in some species externally constricted but not correspondingly constricted internally." The main points of this definition are: (1) the material of the tube consists of sponge-spicules; (2) the tube is open on both ends; (3) the tube has no internal constrictions although they may be present externally.

The sponge-spicules included in the wall-material are obviously connected (as pointed by many authors), with certain *selective properties* of the cytoplasm, which is proved for instance by the fact that together with *Bathysiphon* many other foraminifera exist the test of which does not incorporate any sponge-spicules. This fact is—no doubt—of high diagnostic value. If the evaluation of such selective properties is impossible by the study of cytoplasm alone, their external expression in the form of the test-material and texture is in general easily recognizable. Unfortunately most of the authors have disregarded this fact, introducing within the framework of this genus, species which correspond to it only morphologically.

The presence of the apertures at both ends of the tube of *Bathysiphon* is equally significant. The two opposite apertures define the *two functional directions* of the cytoplasm, mainly the two directions of growing of the test, while similar functions in foraminifera having one aperture are directed only forward, in continuation of the apertural end, or are issued from this end. Therefore, *the difference between the tubes having apertures at the two ends and the tubes having only one aperture, is of cardinal importance*, despite the general similarity of the form. Unfortunately the mostly fragmentary preservation causes much confusion.

The *inner constriction* observed in some monothalamous species may be regarded as very *primitive partitions*, while the passages formed by such constrictions correspond to very large, irregular foramina. Several fossil species recorded as *Bathysiphon*, preserved in fragments and showing such constrictions, are most probably open at one end only. They should be there-

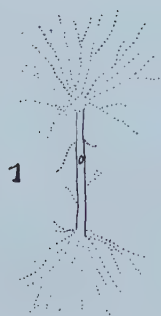
fore transferred to such genera as *Kalamopsis* DE FOLIN or even *Reophax* MONTFORT which include species open at one end of the tube, having more or less incomplete and irregular partitions.

In conclusion, those species whose test does not include sponge-spicules as a main and obviously selected element of their composition, should be excluded from the genus *Bathysiphon*. Nearly forty species are described as belonging to it, but half of them should be placed in other genera, according to the composition and texture of their test. For these excluded species as also for several species assigned to other genera it was necessary to erect new genera in correspondence with the here adopted principles.

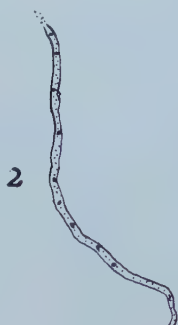
A restudy of the monothalamous foraminifera as a whole leads the writer to the conclusion that their systematic and taxonomic relationship needs a thorough revision. Such a revision is actually in preparation but for the moment, in the connection with the discussion of the genus *Bathysiphon*, a new rearrangement of the tubular *Monothalamia* alone is herewith presented.

Most of the tubular *Monothalamia* are included today in the family RHIZAMMINIDAE, which is defined by CUSHMAN (1950, p. 73) as follows: "Test consisting of a tubular chamber open at both ends; wall with a chitinous lining, and exterior of agglutinated material, sand, sponge spicules or other foraminifera; apertures formed by the open ends of the tubes." Five genera are assigned to this family: *Rhizammina* BRADY, *Marsipella* NORMAN, *Bathysiphon* SARS, *Arenosiphon* GRUBBS, and *Hippocrepinella* HERON-ALLEN and EARLAND. Unfortunately, the main genus, *Rhizammina*, could not be taken as a type of the family, as its genotype, *Rh. algaeiformis* BRADY 1879, does not correspond to the definition of this family. The form assigned by BRADY as the type is a planctonic, branching foraminifer,<sup>1</sup> rather resembling an astrorhizoid form. There are also great differences in figures given by various authors: while BRADY figures three-branched forms, CUSHMAN gives in his "Atlantic Ocean" (pl. 11, figs. 2-3) long, non-branching forms, but in his "Foraminifera" (key, pl. 1, figs. 18-19), arborescent forms. CUSHMAN himself has evidently some doubts as to the identity of this species; analysing ("Atlantic Ocean" part I, p. 32) the records of various scientists he emphasizes: "As the original description says 'free' and it is a dichotomously branching form from cold waters, it is suggested that the Kerimba attached material from shallow tropical waters (recorded by HERON-ALLEN and EARLAND in Trans. Zool. Soc. London, 1915.) may be another thing." From all this it must be concluded that the genus *Rhizammina* could not be included with the tubular *Monothalamia*.

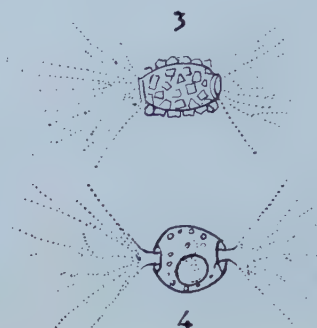
<sup>1</sup> In his original description, Q. J. Micr. Sci., 1879, vol. 19, p. 39, BRADY states: "Test free, tubular, branching, flexible; forming tangled weed-like tufts of indefinite size. The branching does not take place on any definite plan."



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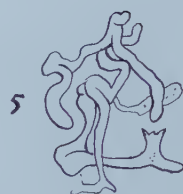


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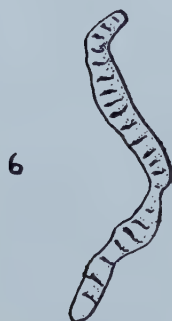


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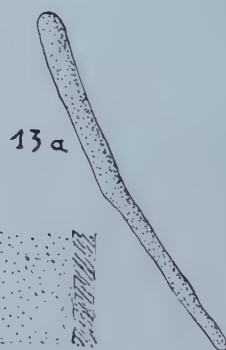
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13a



13b



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15



16



17



Another two genera do not fit with CUSHMAN's *Rhizamminidae*; these are *Arenosiphon* GRUBBS and *Hippocrepinella* HERON-ALLEN and EARLAND. The genotype of *Arenosiphon*, *Ar. gigantea* GRUBBS is described as having circular apertures "at one or both ends of the tubes" (Journ. Paleont. 1939, vol. 13, p. 544), and it is sometimes dichotomously branching at one, broader end of the tube, while in the definition of the genus it is stated with no alternative: "apertures at ends of the tube." It is to be supposed that in reality the species possesses only one aperture, at its broader end, the other being simulated by the damaging of the distal end.

The genus *Hippocrepinella* has been included by CUSHMAN in the *Rhizamminidae* by mistake. Its genotype, *H. hirudinae* HERON-ALLEN and EARLAND, has not (as incorrectly defined by CUSHMAN in "Foraminifera," p. 74) "apertures at two ends," but two at one end: one bigger and near it another, small, inconspicuous, adventitious<sup>2</sup> one.

We do not intend — at least for the time being — to regard the tubular *Monothalamia* as a taxonomically defined family, but as a group including several subfamilies characterized by a similar stage of morphological evolution. In the future it may be possible to define more clearly the mutual relationship of these subfamilies and some of them may be even promoted to the rank of family. Having in common some principal characters of shape, they are arranged in an ascending order, corresponding to the evolution of the test-material. Of course, such characters may be rather

of homeomorphic origin, but as far as they are stable, they may be also of genetic value. The practical problem of systematics in this case is: what is more important, more decisive as a taxonomic factor: the morphology of the test or the wall material? This cannot be answered at the moment and one may even doubt whether any answer can be given at all, as both factors develop simultaneously and more or less independently.

The *Monothalamia* as a whole are raised here to a rank of a suborder of the order *Foraminifera*. If the *Protozoa* in general, including the *Foraminifera*, may be — for comparison with the *Metazoa* — characterized as one-cell organisms fulfilling all the necessary complex physiological functions in the frames of one-cell protoplasm, then the one-chambered *monothalamous foraminifera* are decisively different in their biological style from the many-chambered *polythalamous foraminifera*. The test of a monothalamous foraminifer may be regarded as an expression of *continuous growth* and of continuity of some other physiological functions. The test of polythalamous foraminifer is built up discontinuously, by periodic efforts of the protoplasm, repeating in several acts similar effects. Such differences are of cardinal significance, so that they fully justify the elevation of both, *Monothalamia* and *Polythalamia* to the ranks of suborders of *Foraminifera*.

## II. SYSTEMATIC ARRANGEMENT OF THE TUBULUR MONOTHALAMIA

### Suborder MONOTHALAMIA (new suborder)

Foraminifera, the protoplasm of which is contained

<sup>2</sup> HERON-ALLEN and EARLAND, Journ. Roy. Microsc. Soc., vol. 52, 1932, p. 257.

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(The present figures are based chiefly on the type-figures, but some of them were slightly modified to illustrate more clearly the characteristic features.)

in a single-chambered test of chitinous or of various agglutinated material or of secreted calcareous material.

### GROUP OF TUBULAR MONOTHALAMIA

Tubular, cylindrical, fusiform, ovoid, semiglobular to globular *Monothalamia* open at two opposite ends. Typically free, non-attached, bottom-living foraminifera, mostly marine, few living in fresh-water, exceptionally parasitic in other foraminifera.

The so defined tubular *Monothalamia* include several genera of CUSHMAN's families *Allogromiidae*, *Astrorhizidae* and *Rhizamminidae*; or they include all *Amphitreminae* (Fam. *Lagynidae*) and parts of *Astrorhizinae* (Fam. *Astrorhizidae*) in GALLOWAY's systematics.

#### Subfamily AMPHITREMINAE Galloway cmend. Avnimelech

Tubular *Monothalamia* with chitinous test, sometimes with attached grains of foreign material. Marine, fresh-water and in few cases parasitic in other foraminifera. Known only as recent. Type-genus: *Amphitrema* ARCHER, 1870.

#### Genus *Shepherdella* Siddal, 1880

Entirely chitinous *Monothalamia* with elongate, cylindrical test, with apertures at two pointed ends. Marine. Recent.

Genotype: *Sh. taeniformis* SIDDAL, 1880 (Fig. 1.)  
(SIDDAL, J. D., *Quart. Journ. Micr. Sci.*, vol. 20, p. 131, pl. 15, fig. 1-19 and pl. 16, figs. 1-7, 1880.)

Other species:

*Sh. commatophila* KRUMBIEGEL, 1928.

#### Genus *Marenda* Nyholm, 1951

Similar to *Shepherdella* but the apertures not permanent, although always at the ends. Marine. Recent.

Genotype: *M. nematoideis* NYHOLM, 1951 (Fig. 2)  
(NYHOLM, K. G., *Contr. Cushman Found. Foram. Res.*, vol. II, part 3, pp. 91-95, figs. 1-14, 1951.)

This genus is possibly identical with *Shepherdella*.

#### Genus *Amphitrema* Archer, 1869

Chitinous, short, fusiform *Monothalamia* with truncate ends, both open; a few foreign grains attached to the test. Fresh-water. Recent.

Genotype: *Am. wrightianum* ARCHER, 1869 (Fig. 3)  
(ARCHER, W., *Qu. Journ. Micr. Sci.*, n. s., vol. 9, p. 390, pl. 20, figs. 4-5, 1869.)

Other species:

*Am. lemanense* PENARD, 1903

*Am. rhenanum* LAUTERBORN, 1896

*Am. stenostoma* NUSSLIN, 1884

#### Genus *Diplophrys* Barker, 1868

Chitinous, nearly orbicular or broadly elliptic *Monothalamia*; from two opposite points emanates a tuft of filiform pseudopodia. Fresh water, on submerged plants. Recent.

Genotype: *D. archeri* BARKER, 1868 (Fig. 4).  
(BARKER, J., *Proc. Dublin Microsc. Club*, Dec. 19th 1867, in: *Qu. Journ. Micr. Sci.*, London, 1868, n. s., vol. 8, p. 123. Figs. in: Hertwig, R. and Lesser, E.,

*Arch. Mikrosk. Anat.*, Bonn, 1874, Bd. 10, Suppl. Heft, pl. 3, fig. 9.)

Recent. Vicinities of Dublin (Eire) and of Bonn (Germany)

The other species, "*Diplophrys stercorea* CIENKOWSKI, 1876," is probably not a foraminifer.

#### Genus *Dendrotuba* Rhumbler, 1894

Irregularly winding and anastomosing monothalamous tube open at the ends, parasitic in other foraminifera (*Saccamina* and other). Recent.

Genotype: *D. nodulosa* RHUMBLER, 1894 (Fig. 5)  
(RHUMBLER, L., *Zeitschr. wissenschaft. Zool.*, vol. 57, pp. 606, 611, pl. 25, figs. 123-127, 1894.)

#### Subfamily ARGILLOTUBINAE n. subfam.

Tubular *Monothalamia* with argillaceous test over an internal chitinous lining, often externally constricted, mostly because of drying up. Marine. Only recent species known.

Type-genus: *Argillotuba* n. gen.

#### Genus *Argillotuba* n. gen.

Argillaceous, cylindrical, straight or bent monothalamous test. Recent.

Genotype: *Ar. ("Astrorhiza") vermiformis* (GOËS, 1896) (Fig. 6)

(GOËS, A., *Rep. dredgings operations off the west coast Centr. Amer. etc.*, part XX, Harvard College Museum Comp. Zool., Bull., Cambridge, Mass., vol. 29, p. 20, pl. 1, fig. 9, 1896.)

Other species:

*Ar. ("Bathysiphon") argillaceus* (EARLAND, 1934)

#### Genus *Millettina* n. gen.

Pyriform or fusiform chitino-argillaceous monothalamous test, open at two ends. Marine. Recent.

Genotype: *M. ("Pelosina") distoma* (MILLETT, 1904) (Fig. 7)

(MILLETT, F. W., *Rep. Rec. Foram. Malay Archip.*, part XVII, *Journ. Roy. Micr. Soc. London*, p. 608, pl. 11, figs. 5-6, 1904.)

The species of *Pelosina* possesses only one aperture.

#### Subfamily PSAMMOSIPHONELLINAE n. subfam.

Tubular *Monothalamia*, the agglutinated test of which is composed of mineral grains, mostly quartz. Apertures at both ends.

Type genus: *Psammosiphonella* n. gen.

#### Genus *Psammosiphonella* n. gen.

Tubular arenaceous monothalamous test of round or elliptical cross-section, straight or bent, of even diameter or slightly tapering in one direction without any distinct swelling in any part of the tube; the inner of the tube even, not constricted; apertures at two ends. Stratigraphical range: Ordovician, Silurian, Cretaceous, Tertiary, Recent.

Genotype: *Ps. ("Bathysiphon") arenacea* (CUSHMAN, 1927). Recent. (Fig. 8)

(CUSHMAN, J. A., *Rec. Foram. off the west coast*



America. California Univ., Scripps. Inst. Oceanogr., Bull., Technic. series, vol. 1, p. 129, pl. I, fig. 2, 1927.)

#### Other species:

##### Recent:

**Ps.** ("Bathysiphon") *capbritonensis* (De FOLIN, 1886)

**Ps.** ("Astrorhiza") *compressiuscula* (CHAPMAN, 1924)

**Ps.** ("Astrorhiza") *crassatina* (BRADY, 1881)

**Ps.** ("Rhabdammina") *discreta* (BRADY, 1881) (but not var. *mediterraneis* LACROIX 1928, which is probably a *Kalamopsis*).

**Ps.** ("Bathysiphon") *fusea* (CUSHMAN, 1927)

**Ps.** ("Bathysiphon") *humilis* (Le CALVEZ, 1935)

**Ps.** ("Bathysiphon") *minuta* (PEARCEY, 1900)

**Ps.** *rudis* (Rhumbler, 1931) = *Astrorhiza granulosa* BRADY forma *rudis* RHUMBLER, 1931.

**Ps.** ("Bathysiphon") *rusticum* (De FOLIN, 1886) and var. *minima* De FOLIN, 1886

**Ps.** ("Rhabdammina") *scabra* (HÖGLUND, 1947)

**Ps.** ("Astrorhiza") *vermiculata* (Le CALVEZ, 1935)

##### Tertiary:

**Ps.** ("Rhabdammina") *annulata* ANDREAE, 1890). Oligocene.

**Ps.** ("Bathysiphon") *carapitanus* (HEDBERG, 1937). Middle Tertiary.

**Ps.** *coalingensis* nom. n. = *Rhabdammina cocenica* CUSHMAN and HANNA, 1927. Eocene.

**Ps.** ("Rhabdammina") *cylindrica* (GLAESSNER, 1937. Paleocene.

**Ps.** ("Bathysiphon") *irregularis* (Le ROY, 1944). Miocene.

**Ps.** ("Rhabdammina") *samanica* (BERRY, 1928). Eocene.

**Ps.** ("Bathysiphon") *sanctaerucensis* (CUSHMAN and KLEINPELL, 1934). Miocene.

##### Cretaceous:

**Ps.** ("Bathysiphon") *perampla* (CUSHMAN and GOUDKOFF, 1944. Upper Cretaceous.

**Ps.** ("Bathysiphon") *vitta* (NAUSS, 1947). Cretaceous. Paleozoic:

**Ps.** ("Marsipella") *aggregata* (MOREMAN, 1933). Ordovician.

**Ps.** ("Bathysiphon") *curvus* (MOREMAN, 1930). Silurian; and var. *gracilis* IRELAND, 1930. Silurian.

**Ps.** ("Bathysiphon") *deminutionis* (MOREMAN, 1930). Silurian.

**Ps.** ("Bathysiphon") *exiguus* (MOREMAN, 1930). Ordovician.

**Ps.** ("Bathysiphon") *parallelus* (DUNN, 1942). Silurian.

**Ps.** ("Bathysiphon") *rugosus* (IRELAND, 1930). Silurian.

The generic position of following species remains uncertain, because their definition gives no sufficient and exact details: a) *Bathysiphon capillare* De FOLIN, 1886 has apparently only one aperture; b) the description of *Bathysiphon rufescens* CUSHMAN, 1917 gives no basis for exact opinion.

#### Genus *Oculosiphon* n. gen.

Tubular, arenaceous monothalamous test with a globular or oval swelling in the middle of the tube ("proloculus"); open at two ends. Recent.

Genotype: *Oc.* ("Rhabdammina") *linearis* (BRADY, 1879). Recent. (Fig. 9)

(BRADY, H. B., Notes reticul. Rhizop., "Challenger"

Exped., Qu. Journ. Mic. Sci., London, n. s., vol. 19, p. 37, pl. 3, figs. 10, 11, 1879.)

#### Other species:

*Oc.* ("Rhabdammina") *inaequalis* (Le CALVEZ, 1935). Recent.

#### Genus *Amphitremoidea* Eiscnack, 1937

"Test free, single-chambered, fusiform; wall thick, smooth, finely arenaceous; apertures at the tapering ends of the test." (CUSHMAN, Foraminifera, 1950, p. 72). Silurian, Recent.

Genotype: *Am. citroniforma* EISENACK 1937. Silurian. (Fig. 10)

(EISENACK, Palaeont. Zeitschr., vol. 19, p. 235, 1937.)

#### Other species:

*Am.* ("Marsipella") *granulosa* (BRADY, 1879). Recent.

*Am.* ("Rhabdammina") *fusiformis* (RHUMBLER, 1931). Recent.

#### Genus *Croneisella* Dunn, 1942

"Test free, cylindrical, constricted in the central portion and sometimes slightly bent, with both ends sloping toward pointed necks; wall thin, composed of medium to fine sand-grains, well cemented, surface rough; apertures at ends of necks." — Silurian.

Genotype: *Cr. typa* DUNN 1942. Silurian. (Fig. 11)

(DUNN, P. H., Sil. Foram. Mississippi Basin, Journ. Paleont., vol. 16, p. 335, pl. 44, figs. 10-11, 1942.)

#### Genus *Globosiphon* n. gen.

Arenaceous, globular or ovoid monothalamous test with two apertures at opposite ends. Silurian, Recent.

Genotype: *Gl. sphaeriloculum* (HÖGLUND, 1947 = *Pelosina variabilis* BRADY var. *sphaeriloculum* HÖGLUND, 1947. Recent (Fig. 12)

(HÖGLUND, H., Foram. Gullmar Fjord etc., Uppsala, Univ., Zool. Bidrag, vol. 26, p. 61, pl. 6, figs. 8-11, 1947.)

#### Other species:

*Gl. ramificans* (RHUMBLER, 1936) = *Armorella sphaerica* HERON-ALLEN and EARLAND forma *ramificans* RHUMBLER 1935. Recent.

*Gl.* ("Thurammina") *parvituba* (DUNN 1942). Silurian.

*Gl.* ("Thurammina") *seminaeformis* (DUNN, 1942). Silurian.

#### Subfamily MICATUBINAE n. subfam.

Tubular *Monothalamia* the test of which is essentially constructed of mica-flakes; two apertures at opposite ends.

Type-genus: *Micatuba* n. gen.

#### Genus *Micatuba* n. gen.

Monothalamous tubular test, straight or bent, made of mica-flakes, open at two ends. Recent.

Genotype: *M.* ("Bathysiphon") *flexilis* (HÖGLUND, 1947) (Fig. 13)

(HÖGLUND, H., Foram. Gullmar Fjord, Uppsala, Univ., Zool. Bidrag, Bd. 26, p. 42, figs. 10-11, 1947.)

Subfamily BATHYSIPHONINAE n. subfam.

Tubular *Monothalamia* the test of which is made up predominantly, or otherwise characteristically, of sponge-spicules, demonstrating the selective power of the protoplasm; apertures at two ends. Cretaceous to Recent.

Type genus: *Bathysiphon* M. Sars, 1872.

Genus *Bathysiphon* M. Sars, 1872

Test made up, or characteristically containing sponge-spicules; free, cylindrical, straight or slightly bent, often tapering slightly in one direction, sometimes constricted externally but not internally; apertures at two ends. Cretaceous, Tertiary, Recent.

Genotype: *B. filiformis* M. Sars, 1872. Recent. (Fig. 14)

(SARS, G. O., 1872, Undersogelser ov. Hardangerfjordens Fauna. Vidensk. Selsk. Christiania, Forhandl., Christiania, 1872, Aar. 1871, p. 251. Figs in: De FOLIN, Les Bathysiphons, Soc. Linn., Bordeaux, Actes, vol. 40, ser. 4, pl. 6, figs. 4a-e, 1886.)

Other species:

Recent:

*B. argenteus* HERON-ALLEN and EARLAND, 1913

*B. eachinatum* De FOLIN, 1886

*B. flavidum* De FOLIN, 1886, and var. *giganteus* CUSHMAN, 1917

*B. major* De FOLIN, 1886

*B. nitens* De FOLIN, 1886

*B. papyraceus* CUSHMAN, 1917

*B. ("Rhabdammina") prismaeugina* (De FOLIN, 1887)

*B. rufum* De FOLIN, 1886

*B. spiculosa* (CUSHMAN, 1918) = *Rhabdammina discreta* BRADY var. *spiculosa* CUSHMAN, 1918

*B. ("Marsipella") spiralis* (HERON-ALLEN and EARLAND, 1912)

*B. strictum* De FOLIN, 1886 and var. *obscurum* De FOLIN, 1886

*B. subvitreum* De FOLIN, 1886

Tertiary:

*B. eocenica* CUSHMAN and HANNA, 1927. Eocene.

*B. taurinensis* SACCO, 1893. Aquitanian (Upp. Oligocene)-Miocene.

Cretaceous:

*B. appenninicus* SACCO, 1893. Senonian.

*B. alexanderi* CUSHMAN, 1933. Senonian: Upper Austin.

It is often difficult to prove the identity of fossil species, and especially of older than Tertiary *Bathysiphon*, owing to the epigenesis of sponge-spicules. In these cases the wall-material probably becomes "amorphous," which does not occur in truly arenaceous (sandy) tests.

The species of *Bathysiphon* are relatively deep benthonic organisms, possibly because of their dependence on sponge-spicules, which are more common in greater depth. Most of the species of *Bathysiphon* occur at depths greater than 1000 m. It is a depth of stable and low temperature even in tropical regions. The fossil *Bathysiphon* cannot therefore be used as indicators of climatic conditions. On the other hand they are gen-

erally indicative of sedimentation at greater depth, although a neritic facies is not excluded.

In some recent publications several species, in spite of being divided by inner imperfect partitions, were assigned to *Bathysiphon*, as f. i. *B. abuillotensis* BERMUDEZ, 1949 and *B. nodulosus* BERMUDEZ, 1949, both from Lower Eocene of Cuba, and possibly also *B. angleseensis* CRESPIN, 1950, from the Lower Eocene of Victoria, Australia. These species probably belong to the genus *Kalamopsis* DE FOLIN, 1883, included in family *Reophacidae*.

Genus *Marsipella* Norman, 1878

Tubular, fusiform monothalamous test, straight or slightly curved, tapering towards the two extremities; apertures at two extremities, on the end of long or short necks; wall almost entirely constructed, or containing much sponge-spicules. Recent.

Genotype: *Marsipella elongata* NORMAN, 1878. Recent. (Fig. 15)

(NORMAN, A. M., Genus Haliphysema etc., Ann. and Mag. Nat. Hist. London, ser. 5, vol. 1, p. 281, pl. 16, fig. 7, 1878.)

Other species:

*Marsipella cylindrica* BRADY, 1882. Recent.

*M. dextrospiralis* CHAPMAN and PARR, 1937. Recent.

*M. ("Rhizammina") horrida* (CHAPMAN and PARR, 1937. Recent.

Subfamily TESTULOSIPHONINAE n. subfam.

Tubular *Monothalamia* open at both ends, straight or bent, sometimes with thin side-branches; the chitinous wall is thickly covered with entire or broken tests of other foraminifera together with comparatively few mineral grains. Type-genus: *Testulosiphon* n. gen. Recent.

Genus *Testulosiphon* n. gen.

Cylindrical, unbranched chitino-arenaceous tube, often tapering toward the ends; apertures terminal; the wall mostly encrusted with tests of other foraminifera (mainly *Globigerina*). Recent.

Genotype: *T. ("Rhizammina") indivisa* (BRADY, 1884) (Fig. 16)

(BRADY, H. B., Rep. foramin. dredged by H. M. S. Challenger, Rep. Challenger Exped., London, Zool., pt. 22, vol. 22, p. 277, pl. 29, figs. 5-7, 1884.)

Genus *Testulorhiza* n. gen.

Cylindrical chitinous tube with fine side-branches; apertures at the two extremities, also the side-branches are open; the tube is agglutinated with foraminifera-tests (mainly *Globigerinae*), but the branches are nearly totally naked. Recent.

Genotype: *T. ("Rhizammina") globigerinifera* (HOFKER, 1930) (Fig. 17)

(HOFKER, J., Foramin. Siboga-Exped., part II, in: Siboga-Exped.; Uitkomst. zool. botan. oceanogr. en geol. gebied, versameld in Nederl. Oost-Indië 1899-1900. Leiden, Monographie 4a, p. 117, pl. 51, fig. 2, 1930.)



## RECAPITULATION OF TUBULAR MONOTHALAMIA

Test material	Chitinosae	Argillacea	Arenacea	Micacea	Spiculotestacea	Testulotestacea
Subfamilies	Amphitreminae	Argillotubinae	Psammosiphonellinae	Micatubinae	Bathysiphoninae	Testulosiphoninae
Shape						
Cylindrical	Shepherdella Marenda	Argillotuba	Psammosiphonella	Micatuba	Bathysiphon	Testulosiphon
Cylindrical with side-branches	—	—	—	—	—	Testulorhiza
Cylindrical with "proloculum"	—	—	Oculosiphon	—	—	—
Fusiform	Amphitrema	Millettina	Amphitremonoidea Croneisella	—	Marsipella	—
Globular, ovoid	Diplophrys	—	Globosiphon	—	—	—
Irregularly winding	Dendrotuba	—	—	—	—	—

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## REFERENCES

- BERMUDEZ, P. J., 1949, Tertiary smaller Foraminifera of the Dominican Republic. *Cushman Lab. Foramin. Res., Spec. Publ.* 25.
- BIEDA, F., 1950, Sur quelques foraminifères nouveaux ou peu connus du flysch des Karpates Polonaises. *Ann. Soc. géol. Pologne*, vol. XVIII, 1948.
- CRISPIN, I., 1950, Some Tertiary Foraminifera from Victoria, Australia. *Contr. Cushman Foundat. Foramin. Res.*, I, 3-4.
- CUSHMAN, J. A., 1917, New species and varieties of foraminifera from the Philippines and adjacent waters. *U. S. Nat. Mus., Proc.*, vol. 51, No. 2172.
- , 1918, The Foraminifera of the Atlantic Ocean. Part I; Astrorhizidae. *Smithsonian Inst. - U. S. N. M., Bull.* 104.
- , 1927, Recent foraminifera from off the West Coast of America. *California Univ., Scripps Inst. Oceanogr., Bull. Techn. Ser.* vol. I.
- , 1933, New American Cretaceous foraminifera. *Contr. Cushman Lab. Foramin. Res.*, vol. 9, pt. 3, no. 134.
- , 1946, Upper Cretaceous Foraminifera of the Gulf Coastal region of the United States and adjacent areas. *U. S. Dep. Int., Geol. Surv., Prof. Pap.* 206.
- , 1950, *Foraminifera, their classification and economic use*. 4th ed., second printing, Harvard Univ. Press., Cambridge, Massachusetts.
- and GOUDKOFF, P. P., 1944, Some Foraminifera from the Upper Cretaceous of California. *Contr. Cushman Lab. Foramin. Res.*, vol. 20, pt. 3.
- and HANNA, G. D., 1927, Foraminifera from the Eocene near Coalinga, California. *Calif. Ac. Sc., Proc.*, ser. 4, vol. 16, no. 8.
- and KLEINPELL, R. M., 1934, New and unrecorded foraminifera from the California Miocene. *Contr. Cushman Lab. Foramin. Res.*, vol. 10, pt. 1.
- and RENZ, H. H., 1946, The foraminiferal fauna of the Lizard Springs of Trinidad, British West Indies. *Cushman Lab. Foramin. Res., Spec. Publ.*, no. 18.
- , 1947, Further notes on the Cretaceous foraminifera of Trinidad. *Contr. Cushman Labor. Foramin. Res.*, vol. 23, pt. 2.
- and SIEGFUS, S. S., 1942, Foraminifera from the type area of the Kreyenhagen shale of California. *Trans. San Diego Soc. Nat. Hist.*, vol. IX, no. 34.
- DUNN, P. H., 1942, Silurian foraminifera of the Mississippi Basin. *Journ. Paleont.*, vol. 16.
- EARLAND, A., 1934, "Discovery" Reports, Part. III: The Falkland sector of the Antarctic; Foraminifera. "Discovery" Committee, Colonial Office, London, vol. 10.
- ELLIS, B. F., and MESSINA, A. R., 1940 ff., Catalogue of Foraminifera. *Amer. Mus. Nat. Hist., N. Y.*
- FOLIN, L. DE, 1886, Les Bathysiphons; premières pages d'une monographie du genre. *Soc. Linn. Bordeaux, Actes*, vol. 40.
- GALLOWAY, J. J., 1933, *A Manual of Foraminifera*, Bloomington, Indiana.
- HEDBERG, H. D., 1937, Foraminifera of the middle Tertiary Carapita formation of northeastern Venezuela. *Journ. Paleont.*, vol. 11.
- HERON-ALLEN, E. and EARLAND, A., 1913, Clare Island Survey, Part 64: Foraminifera. *Roy. Irish Ac., Proc.*, vol. 31.
- HÖGLUND, H., 1947, Foraminifera in the Gullmar Fjord and the Skagerak. *Uppsala Univ., Zool. Bidrag.*, vol. 26.

- HOFKER, J., 1932, Notizen über die Foraminiferen des Golfes von Neapel; III: Die Foraminiferen der Ammontatura. *Staz. Zool. Napoli Pubbl.*, vol. 12, fasc. 1.
- IRELAND, H. A., 1939, Devonian and Silurian foraminifera from Oklahoma. *Journ. Paleont.*, 1939, vol. 13.
- LE CALVEZ, 1935, Sur quelques foraminifères de Villefranche et de Banyuls. *Arch. Zool. Exper. Gen., Notes et Revues*, t. 77.
- LE ROY, 1944, Miocene foraminifera from Sumatra and Java, Netherlands East Indies. Part 1: Miocene foraminifera of Central Sumatra, Netherlands East Indies. *Colorado School of Mines, Quart.*, vol. 39, no. 3.
- MOREMAN, W. L., 1930, Arenaceous foraminifera from Ordovician and Silurian limestones of Oklahoma. *Journ. Paleont.*, vol. 4.
- NAUSS, A. W., 1947, Cretaceous microfossils of the Vermilion area, Alberta. *Journ. Paleont.*, vol. 21.
- NYHOLM, K. G., 1951, A monothalamous Foraminifer *Marenda nematoides* n. gen. n. sp. *Contr. Cushman Found. Foramin. Res.*, vol. II, part 3, pp. 91-95. Oct. 1951.
- PEARCEY, F. G., 1900, On some deep sea Rhizopods found in the Clyde area. *Millport Mar. Biol. Stat., Commun.*, No. 1.
- SACCO F., 1893, Le genre *Bathysiphon* à l'état fossile. *Bull. Soc. Geol. France*, ser. 3, t. 21.
- SARS, G. O., 1872, Undersøgelser over Hardangfjordens Fauna. *Vidensk. Selsk. Christiania, Forhand.*, aar 1871.
- THALMANN, H. E., 1950, New names and homonyms in Foraminifera. *Contr. Cushman Foundat. Foramin. Research*, vol. I, parts 3-4.

## 59. CRETACEOUS FORAMINIFERA FROM THE FRANCISCAN CALERA LIMESTONE OF CALIFORNIA\*

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The Franciscan formation was described by A. C. LAWSON in 1895. The name was taken from the city of San Francisco near which the extensive outcrops of the formation were first studied and described. Outcrops classified as Franciscan extend for many miles north and south of San Francisco in the coast ranges. Its true relationship to older formations is not clearly defined as it is usually in fault contact. Abundant evidence of structural deformation and consequent metamorphism is usually present. In the type locality Lawson listed five formations as constituting the Franciscan group, namely, beginning at the top:

Bonita Sandstone 1400'±  
Ingleside Chert (Radiolarian Chert) 530'±  
Marin Sandstone 1000'±  
Sausalito Chert (Radiolarian Chert) 900'±  
Cahil Sandstone (including Calera Limestone member and volcanic rocks) 2560'.

The three sandstone members are described as being very similar. They are "massive, obscurely bedded sandstone of dark greenish gray color and medium texture." They are well cemented and besides the usual high percentage of quartz contain unusual amounts of feldspar, hornblende, biotite, and zircon besides pieces of chert, schist, and volcanic rock. Carbonaceous fragments and seams of coal are also common.

The Calera limestone member is described as "a gray compact rock of aphanitic texture, resembling lithographic limestone. Thin sections of the rock show a great many clear hyaline spots, the largest measuring a half millimeter across. These spots are the remains of foraminiferal shells." Lawson considered the limestone to be a chemical precipitate in which foraminifera became sporadically entombed. It is traversed with many veinlets of calcite and may be generally described as well bedded. The Cahill sandstone is estimated to be 2565' thick and consists of 60' of limestone (Calera limestone) with 500' of sandstone below and 2000' above.

The age of the Franciscan has long been a matter of conjecture and controversy. Usually, it has been considered as upper Jurassic. N. L. TALIAFERRO, who has probably spent more time on the problem than anyone else, considers the Franciscan to be a part of the Knoxville and combines the two names, giving the included formations a group status. He ascribes an upper Jurassic age to the interval. The total thickness of the Franciscan - Knoxville is not known but with exposed sections up to 10,000 feet thick TALIAFERRO estimates a possible thickness of 30,000 feet for the group. With these facts established for the beds in the Huasna district, the east side of the Diablo Range, and on the west side of the Sacramento valley, the question which naturally arises is, are the Franciscan rocks of the San

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Francisco peninsula equivalent to these better known sections? In the few instances where fossils have been found, as at Slate's Hot Springs, western Monterey County and more recently in the San Francisco area (yet unpublished), the age has been determined as middle or upper Cretaceous.

In November, 1950, the writer, in company with C. E. STURZ, visited the prominent outcrop of Calera limestone at Rockaway Beach, San Mateo County and collected extensively from the weathered portions of the outcrop. Of these samples, one large fragment found at the foot of the cliff, half buried in red clay and exposed by the action of the tide, contained visible foraminifera on the weathered surface. In the laboratory the weathered boulder was washed and brushed over a fine sieve and the screenings collected and dried. From this residue a number of fairly well preserved foraminifera were picked. Most of the species are of the genus *Globotruncana* but there are a number of other genera, many of which are not sufficiently well preserved to warrant generic identification. On a cursory examination it was at once evident that these specimens were identical to those so often seen in thin sections of the limestone and in a state of preservation far better than any hitherto reported or described from these beds.

The first forams found weathered out of Franciscan limestone were those discovered by JOSÉ HENRIQUE PANTIN in 1946, at the time a graduate student at Stanford University, working on the possibilities of correlating certain limestones by means of heavy minerals. A few of these forams were submitted to HANS E. THALMANN, who made tentative identifications. The same fauna was later collected by H. H. BAILEY and DONALD E. EVERHART of the United States Geological Survey and sent to the late J. A. CUSHMAN and Miss RUTH TODD. These authors (see Reference 1) described and figured the identifiable specimens in 1948, and concluded that the fauna was younger than Jurassic and probably of Lower Cretaceous age.

The first foraminifera mentioned specifically, however, were those listed by HANS E. THALMANN (see Reference 12) from the Franciscan limestone at the Permanente Quarry, Santa Clara County, California, in 1942, and in another short paper (Reference 13) from a limestone collected by N. L. TALIAFERRO from near Laytonville, Mendocino County, California (1943). THALMANN studied both rocks in thin-sections and cited the common *Globotruncana* as *G. renzi* THALMANN-GANDOLFI occurring together with *Globigerina cretacea* D'ORB. Other genera commonly found in Cretaceous beds were listed, and it was, therefore, concluded that the age of both these limestones was at least Turonian. THALMANN stated further (Reference 13) that "The Laytonville limestone, therefore, is to be regarded as a synchronous deposit of the Calera limestone of the Quarries of the Permanente Cement

Company, Santa Clara County, and of the Calera limestone at its type locality in Calera Valley, San Mateo County, California."

The latest paper on the Calera limestone is that by GEORGE W. WALKER of the U. S. Geological Survey (see Reference 14). WALKER considers the Calera limestone of the type locality to be identical to that at the Permanente Cement Company in Santa Clara County and to the isolated outcrops above the Spring Valley lakes in San Mateo County. All of the foraminiferal data bear this out.

The foraminifera found by C. E. STURZ and the writer were submitted to HANS E. THALMANN in the summer of 1951. He was of the opinion that the fauna indicated Cenomanian age and suggested sending specimens to HANS BOLLI of Trinidad, one of the foremost specialists in this field. This suggestion was followed in May, 1951; his reply came the following month. Referring to the works of REICHEL and SIGAL in Europe, H. BOLLI wrote "The more common species of your slide would in the good old days have been determined without much hesitation as *G. appenninica* (probably var. *typica* of GANDOLFI). Range: middle to upper Cenomanian for var. *typica*. Comparing your form with the curved ventral sutures with REICHEL's figures, it might fall into the neighborhood of *Globotruncana sigali*. REICHEL range: lower Turonian. But, should any sutural or multiple umbilical apertures be found in better preserved specimens, REICHEL would then place the type under *G. (Rotalipora) appenninica* or



Text Fig. 1: Pen-drawings by H. Bolli, Pointe-a-Pierre, Trinidad of smaller isolated *Globotruncanae* species collected by C. C. Church and C. E. Sturz at Calera Limestone type locality.

*G. (Thalmaninella)* sp." (See: Text fig. 1). In a letter dated September 18, 1951, H. BOLLI stated that he had succeeded in exposing the interiomarginal aperture of this species and the sutural apertures of the last two chambers became clearly visible. (See Text fig. 2).



Text Fig. 2: Pen drawing of *Globotruncana* (*Rotalipora*) *apenninica* Renz var. *typica* Gandolfi from Calera Limestone type locality, Rockaway Beach, San Mateo County, California (Drawn by H. Bolli).

He then concludes that "This makes the form a *Rotalipora* which compares best with *Globotruncana* (*Rotalipora*) *apenninica* var. *typica* GANDOLFI. The variety is described from the Cenomanian (Middle or Upper)."

Of a smaller form of *Globotruncana* which he examined he said, "It appears to compare well with *G. apenninica* var. B. GANDOLFI, the name of which was altered by REICHEL into *G. (Globotruncana) stephani* GANDOLFI var. *turbinata*. REICHEL range: Middle to Upper Cenomanian (after GANDOLFI). "Based on this, a Middle to Upper Cenomanian age of the Franciscan Limestone is likely, but to ascertain it on a *Globotruncana* basis more and even better preserved specimens should be available."

Besides the two identified species of *Globotruncana* there are at least ten other genera and species including *Pseudoclavulina* sp., *Pleurostomella* sp., *Anomalina* sp., *Dentalina* sp., *Globigerina* sp., *Cibicides* sp., *Gyroldina* sp. cf. *G. depressa* (ALTH) and *Schackoina cenomana* (SCHACKO). The last named species was described from the Cenomanian of Germany. The fauna as a whole has a decidedly basal Upper Cretaceous aspect.

The additional information afforded by this unusual fauna tends to support the conclusion that the Calera limestone is somewhere close to the middle Cretaceous or basal Upper Cretaceous in age.

It now seems to be the general conclusion of most workers in California that Franciscan type rocks cover

a wide range in age from upper Jurassic to middle or even basal upper Cretaceous. Further detailed work will be necessary to narrow the age limits of the various members of the Franciscan formation.

## REFERENCES

1. CUSHMAN, J. A. and TODD, RUTH. A Foraminiferal Fauna from the New Almaden District, California: Cushman Lab. for Foram. Res., Vol. 24, Pt. 4, pp. 90-98, 1948.
2. DAVIS, E. F. The Franciscan Sandstone: Bull. Dept. Geol. Univ. Calif. Pub., Vol. 11, No. 1, pp. 1-44, March, 1918.
3. LAWSON, A. C. U. S. Geological Surv. Atlas, San Francisco Folio (No. 193) 1915.
4. MIRANDA, J. J. Insoluble Residues of the Calera Limestone from its Type Locality, Calera Valley, San Mateo Co. Calif: Unpub. Thesis, (M.S.)
5. NOMLAND, J. O. and SCHENCK, H. G. Cretaceous Beds at Slate's Hot Springs, Calif: Univ. Calif. Pub. Bull. Dept. Geol. Sci., Vol. 21, No. 4, pp. 37-49, 1932.
6. PANTIN, J. H. Insoluble Residues of the Calera Limestone in Santa Clara County, Cal: Unpub. Thesis (M.A.), Stanford University, 1946.
7. REED, R. D. Geology of California: Am. Assoc. Petrol. Geol., pp. 90-91, 1933.
8. REICHEL, MANFRED. Observations sur les *Globotruncana* du gisement de la Breggia (Tessin): *Eclogae Geol. Helv.*, Vol. 42, No. 2, pp. 596-617, 1949.
9. SIGAL, J. Note sur les genres de Foraminifères *Rotalipora* BROTZEN 1942 et *Thalmaninella*: *Revue de l'Institut français du Pétrole et Annales des Combustibles liquides*, Vol. 3, No. 4, 1948.
10. TALIAFERRO, N. L. Geologic History and Structure of the Central Coast Ranges of California: Calif. Div. Mines, Bull. 118, pt. 2, pp. 119-163, 1941.
11. ———. Geology of the San Francisco Bay Counties: *ibid.*, Bull. 154, pp. 117-150, 1951.
12. THALMANN, HANS E. *Globotruncana* in the Franciscan Limestone, Santa Clara County, California: *Geol. Soc. America, Bull.*, vol. 53, No. 12, pt. 2, p. 1838, 1942.
13. ———. Upper Cretaceous age of the "Franciscan" limestone near Laytonville, Mendocino County, California: *ibid.*, vol. 54, Nr. 12, p. 1827, 1943.
14. WALKER, GEORGE W. The Calera Limestone: California Div. Mines Spec. Report 1-B, 1950.



## 60. ZONAL ANALYSIS OF THE LOWER GAULT OF KENT BASED ON FORAMINIFERA

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**ABSTRACT**—Based on the frequency-occurrence of some species three foraminiferal zones are recognized in the Lower Gault of the type locality of Folkestone. Their lateral extension at Dunton Green and Sevenoaks is discussed. Comments are given on works dealing with foraminiferal zones of more or less contemporaneous formations on the Continent. The Dunton Green-Sevenoaks foraminiferal fauna is briefly described in the appendix.

## INTRODUCTION

When re-examining the foraminifera from the Lower Gault of Folkestone, the opportunity was taken to analyse statistically the foraminiferal content of each of the samples examined to determine progressive changes in the composition and distribution of the foraminiferal fauna in the various beds of the Lower Gault, and to see if these were zonally significant. In this analysis the actual number of specimens of each species found in 0.5 grams of washed material collected from a 120-mesh screen was counted. When the occurrence of a species exceeded 100, it was recorded as a 'flood form.' Broken, immature and ill-preserved specimens were ignored. The result of this statistical analysis shows that approximately ninety percent of the species recorded are distributed throughout the Lower Gault and are therefore of no zonal value. Ten percent, however, have either a limited vertical range or occur in great abundance only at certain horizons. These species serve as good index forms and can be used to recognise three foraminiferal zones in the Lower Gault. The zones were first established at Copt Point (East Cliff) Folkestone, whence a total of 58 samples were examined at vertical intervals of six inches. Later their lateral extension was investigated both at the type locality and at two inland exposures of Gault at Dunton Green and at Sevenoaks.

The writer is indebted to Alan Wood and C. D. Ovey for their valuable suggestions. He is grateful to R. Casey for his help in obtaining samples from the correct horizons of the Gault at Folkestone and Sevenoaks. He also wishes to thank C. W. Wright for helping him while collecting samples from Dunton Green during one of the half-day excursions organised for the Eighteenth Session of the International Geological Congress held in London, in 1948.

## ZONAL ANALYSIS OF THE FORAMINIFERA

The stratigraphical distribution and relative abundance of zonally important species is shown diagrammatically in Text Fig. 1. It will be seen from this that some species like *Hormosina folkestoniensis* Khan, *Vaginulina neocomiana* Chapman, *Spiroplectinata annectens* (Parker and Jones) have a short vertical distribution,

while others, such as *Bolivina textilarioides* Reuss, *Pleurostomella alternans* Schwager, *Siphogenerina asperula* (Chapman), *Epistomina spinulifera* (Reuss) and *Arenobulimina macfadyeni* Cushman, though having a wider vertical range, occur in greatest abundance only within restricted limits. Thus, based on the frequency-occurrence of certain species, the following three foraminiferal zones can be recognised in ascending order.

## I. BOLIVINA TEXTILARIOIDES-PLEUROSTOMELLA ALTERNANS ZONE

Characterised by:—

*Bolivina textilarioides* Reuss, *Pleurostomella alternans* Schwager, *Hormosina folkestoniensis* Khan, *Vaginulina neocomiana* Chapman, *Dorothia gradata* (Berthelin) var. *dispana* Chapman, *Haplophragmoides latidorsatum* (Bornemann), *Verneuilina chapmani* Ten Dam, *Marssonella oxycona* (Reuss), *Dorothia gradata* (Berthelin), *Epistomina spinulifera* (Reuss)

## II. SIPHOGENERINA ASPERULA ZONE

Characterised by:—

*Siphogenerina asperula* Chapman, *Haplophragmoides latidorsatum* (Bornemann), *Lagena sulcata* (Walker and Jacob)

## III. EPISTOMINA SPINULIFERA-ARENOBULIMINA MACFADYENI ZONE

Characterised by:—

*Epistomina spinulifera* (Reuss), *Arenobulimina macfadyeni* Cushman, *Pleurostomella alternans* Schwager, *Spiroplectinata annectens* (Parker and Jones), *Bifarina tenuilissa* Tappan, *Tritaxia pyramidata* Reuss.

Zone I can be distinguished by the great abundance of *B. textilarioides* Reuss and *P. alternans* Schwager, but it contains also some less abundant species such as *H. folkestoniensis* Khan, *V. neocomiana* Chapman and *D. gradata* var. *dispana* Chapman all of which are confined to it. The occurrence of *Marssonella oxycona* (Reuss), *Verneuilina chapmani* Ten Dam and *Dorothia gradata* (Berthelin) is predominant in this zone, but the species are also found outside it.

Zone II has few species peculiar to it, but *Siphogenerina asperula* (Chapman) predominates. It is, however, almost devoid of species characteristic of Zones I and III and *S. asperula*, the index species, has a very short vertical range being limited only to the Lower Gault. Further, *Lagena sulcata* (Walker and Jacob) makes its first appearance in this zone.

Zone III has also its own assemblage distinct from those of Zones I and II. Such species as *Bifarina tenuilissa* Tappan, *Spiroplectinata annectens* (Parker and Jones) make their appearance here for the first time.





The greatest abundance of *Epistomina spinulifera* (Reuss) and *Arenobulimina macfadyeni* Cushman is also confined to this zone.

The exact limits of these foraminiferal zones, as would be expected, are not very well defined and one zone merges into another quite insensibly. Roughly the upper limit of Zone I can be placed 13 feet above the base of the Gault, as upwards from this point the dominant zonal species *Bolivina textularioides* Reuss, begins to decline in abundance, while *Siphogenerina asperula* (Chapman) of the succeeding zone gradually begins to become prominent. Further, *Pleurostomella alternans* Schwager, *Marssonella oxycona* (Reuss), *Verneuilina chapmani* ten Dam and *Dorothia gradata* (Berthelin), after attaining their maximum abundance, begin to decline in numbers. The boundary between Zone II and Zone III can be placed 22 feet above the base of the Gault, from which point onwards *Siphogenerina asperula* (Chapman) ceases to be a dominant form, but *Epistomina spinulifera* (Reuss) and *Arenobulimina macfadyeni* Cushman begin to increase in abundance. The upper limit of Zone III can be fixed only after examining material from higher beds of the Gault. With these limits the thickness of Zone I will be 13 feet and it will comprise Bed I of PRICE (1874) and a greater part of Bed II, that of Zone II will be 9 feet and it will include part of Bed II, Beds III, IV, V, VI and some part of Bed VII. The remaining part of Bed VII and Bed VIII will fall within the limits of Zone III. The correlation between the foraminiferal zones and the ammonite divisions of PRICE (op. cit) and SPATH (1923-43, p. 668) is illustrated in Table 1.

#### COMPARISON WITH OTHER LOCALITIES

With a view to confirm the lateral extension of these foraminiferal zones a series of samples was obtained from the middle of each zone from about 100

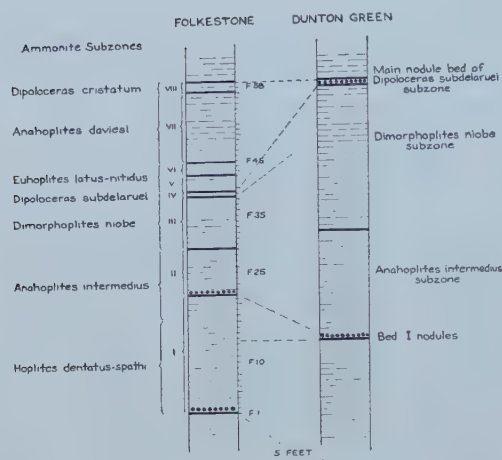
yards distant from Copt Point, and two of the samples examined from Beds VII and VIII were taken from Eastwear Bay. Besides the type locality, material was also examined from two inland exposures of Gault at Dunton Green and Sevenoaks.

#### THE GAULT OF DUNTON GREEN

The Gault exposed in the pit of the Dunton Green Brick Tile and Pottery Works near the Dunton Green Railway Station has recently been studied by C. W. Wright and H. D. Thomas (1946). The chief features of the Gault of this locality as compared with that of the type section of Folkestone are the great expansion of the *Anahoplites intermedius* sub-zone which is here twice as thick as at Folkestone, and the attenuation of 9½ feet thick clays of the *Euhoplites lautus*, *E. nitidus*, *Anahoplites daviesi* and *Diploceras cristatum* sub-zones of Folkestone into a 3 or 4 inches thick nodular bed at Dunton Green. The lowest horizon exposed in the Dunton Green pit is the top part of the *Hoplites dentatus-spathi* sub-zone, i. e. equivalent of Bed I of Folkestone which is represented by dark clays about a foot thick and is overlain by a nodular bed containing ammonites characteristic of both the *Hoplites dentatus-spathi* and the succeeding *Anahoplites intermedius* sub-zone, thus it represents the top of the *Hoplites dentatus-spathi* and the base of the *Anahoplites intermedius* sub-zones. *Dimorphohoplites niobe* Spath, the index species of Bed III, appears 4 feet below the main nodule bed, but the authors were neither able to fix the Lower, nor the upper limits of this sub-zone. *Diploceras subdelaruei* Spath occurs about 5 inches below the main nodule bed, but there is no direct evidence of the presence of the *Euhoplites lautus-nitidus* sub-zone at Dunton Green. The relation of the Lower Gault of Dunton Green with that of the type locality of Folkestone is shown in Text Fig. 2.

AMMONITE DIVISIONS			FORAMINIFERAL ZONES
ZONES	SUBZONES	BEDS	
<i>Euhoplites lautus</i> (Euhoplitan)	<i>Diploceras cristatum</i>	VIII	<i>Epistomina spinulifera</i> - <i>Arenobulimina macfadyeni</i>
	<i>Anahoplites daviesi</i>	VII	
	<i>Euhoplites lautus</i> - and <i>nitidus</i>	VI, V	
<i>Hoplites dentatus</i> (Hoplitan)	<i>Diploceras subdelaruei</i>	IV	<i>Siphogenerina asperula</i>
	<i>Dimorphohoplites niobe</i>	III	
	<i>Anahoplites intermedius</i>	II, I	<i>Bolivina textularioides</i> - <i>Pleurostomella alternans</i>
	<i>Hoplites dentatus</i> - and <i>spathi</i>	I	

Table 1: The correlation between the Ammonite and Foraminifera zones



Text Fig. 2. Relation between the Gault of Folkestone and Dunton Green. Position of Samples indicated by small horizontal lines on right hand side of Folkestone section.

From this locality the following eight samples have been examined:

- Sample D1 From Bed I nodules (i. e. top of the *dentatus-spathi* and base of the *intermedius* sub-zone)
- Samples D2-D4 From the middle of the *intermedius* sub-zone with an interval of 1 foot between each sample.
- Samples D5, D6 From the *niobe* sub-zone, 5 and 4 feet below the Dunton Green nodule bed respectively.
- Sample D7 From 2 inches below the Dunton Green nodule bed.
- Sample D8 From the Dunton Green nodule bed.

### THE GAULT OF SEVENOAKS

The Sevenoaks Gault Section has been comparatively recently excavated by the Sevenoaks Brick Works Ltd., and lies  $\frac{3}{4}$  of a mile north east of Sevenoaks (Bat and Ball) Railway Station and about  $\frac{1}{2}$  of a mile north of Sevenoaks Brick Works Office buildings. The succession here is in the main similar to that observed in the pit at Dunton Green. The *Hoplites dentatus-spathi* sub-zone, however, is not exposed at the surface and the present working floor of the pit lies on the *Anahoplites intermedius* sub-zone which appears to be of even greater vertical thickness than at Dunton Green. Below the main nodule bed which, in a condensed form, represents Beds V to VIII of the type locality of Folkestone, the *Diploceras subdelaruei*, *niobe* and *intermedius* sub-zones are all exposed in descending order.

The following samples have been studied from this locality:

- Samples S1, S2 From the *intermedius* sub-zone 20 and 15 feet below the main nodule bed respectively.
- Samples S3, S4 From the *niobe* sub-zone 8 and 6 feet below the main nodule bed respectively.
- Sample S5 From the *niobe* or *subdelaruei* sub-zone 4 feet below the main nodule bed.
- Samples S6, S7 From the *subdelaruei* sub-zone 2 feet and 2 inches below the main nodule bed respectively.
- Sample S8 From the main nodule bed.

An examination of these samples shows that, while the foraminiferal zones hold good laterally at Folkestone, they are not as distinct at Dunton Green and Sevenoaks as they are seen at the type locality. The foraminiferal fauna of these localities compared with Folkestone is generally poor both as regards the number of species and the number of individuals (see appendix, p. 80). Nevertheless, in both localities the distribution of all the characteristic species of the three foraminiferal zones is more or less the same as that at Folkestone, although these species are not present in the same degree of abundance. *Bolivina textularioides* Reuss and *Pleurostomella alternans* Schwager, the two index forms of Zone I, have a restricted range both at Dunton Green and at Sevenoaks. The latter form is found to be frequent in the *Anahoplites intermedius* sub-zone (Bed II) and is extremely rare at higher horizons, and the former is likewise confined to the *Hoplites dentatus-spathi* and *Anahoplites intermedius* sub-zones but is of very rare occurrence. The rarity of this species is not difficult to understand, for at Dunton Green only the top of the *dentatus-spathi* sub-zone is exposed, while at Sevenoaks the succession commences with the overlying *intermedius* sub-zone, and the maximum abundance of this species is seen at Folkestone stratigraphically below the sub-zones exposed in either localities. *Siphogenerina asperula* (Chapman) the index species of Zone II, is also restricted to the *Dimorphoplites niobe* and *Diploceras subdelaruei* sub-zones but is rare. The horizons at which the two characteristic species of foraminiferal Zone III, *Arenobulimina macfadyseni* Cushman and *Epistomina spinulifera* (Reuss) are found in great abundance at Folkestone, i. e. in Beds VII and VIII, have been condensed at Dunton Green and Sevenoaks into a few inches thick nodular bed, which seems to be the cause of the rarity of these forms. The very feeble development of not only *E. spinulifera*, but of all other species belonging to this genus, is very striking. It appears that conditions were in some way unfavourable for the development of these species at Dunton Green and Sevenoaks.



In conclusion, it may be added that, the behaviour of zonally important species in the higher beds of the Gault is a matter of speculation. It is quite probable that, with a recurrence of conditions favourable to their growth, some of them may again become abundant at some horizons in the Upper Gault, although it is unlikely that individually they will be found again in the same association with other species. However, the possibility of some modifications in the zones proposed here, as a result of examination of material from higher beds, can not be ruled out. It is only after the entire section of Gault has been studied fully that the zoning will be complete and placed on a firmer basis.

### CONTEMPORANEOUS ZONES ON THE CONTINENT

It may not be out of place to comment here briefly on foraminiferal zones of mainly contemporaneous deposits on the Continent.

The micro-faunal divisions of the Lower Cretaceous of Wenden am Mittellandkanal (North West Germany) have been described by EICHENBERG (1935). He has selected 184 species which seems to be of zonal value and has given an assemblage of foraminifera and other micro-organisms characteristic of various zones of the Lower Cretaceous stages. The Albian zones considered by him are as follows:

- Zone of *Neohibolites minimus* Stoll
- Zone of *Leymeriella regularis* Brug
- Zone of *Leymeriella tardefurcata* Leym
- Zone of *Acanthohoplites nolani* Seunes

In England these zones correspond to the Lower Albian and represent the equivalent of the Folkestone Beds which underlie the Gault.

In a more detailed work on the foraminiferal divisions of the Lower Cretaceous of Wenden HECHT (1938) uses a much larger number of species as compared with those employed by EICHENBERG. The most interesting feature of HECHT's work is his recognition of microbiostratigraphical divisions corresponding to each of the stratigraphical and palaeontological subdivisions. This is the first attempt of its kind in which such foraminiferal divisions have been made, foraminifera having previously only been employed in the recognition of zones. From the base of the Neocomian group to the top of the *Leymeriella* group, HECHT recognised 3 foraminifera-stages, 6 foraminifera-groups, 20 foraminifera-zones and 2 foraminifera-horizons. A comparison between mesa- and micro-divisions shows that they agree very closely not only in zones but also in the major divisions of groups and stages. The Aptian does not seem to be recognizable micropalaeontologically as an independent stage and is grouped with the Albian under HECHT's *Gaudryina* - (16) stage. Unfortunately all the species in this work have been distinguished by numerical means which make a comparison rather difficult.

In France MARIE has contributed a series of papers on the foraminiferal zones of the Middle Cretaceous of Saint-Florentin (Yonne), 1939, Gault of Aube (1941), Gault of Wissant (1941a), Gault of Paris Basin (1941b) and the Albian Clays of Pays de Bray (1941c). Those of Saint-Florentin, Aube and Wissant are of interest to us. In the Middle Cretaceous of Saint-Florentin, MARIE distinguished six foraminiferal zones, which correspond to various stratigraphical divisions ranging from Middle Albian to Cenomanian. The foraminiferal zone of the blue-black clays of the Middle Albian at Saint-Florentin is equivalent to PRICE's Bed I at Folkestone and is characterised by *Citharina* cf. *dis-cors* Koch (now recognised as *Vaginulina mariei* Khan, 1950, p. 270) and the var. *gracilis* Marie, *Citharina orbigny* Marie and *Flabellina* sp. With the exception of one none of these species occur in the Gault of England, and the species of *Citharina* and other related forms are found to appear at horizons much above Bed I.

Five zones are recognised in the Gault of the Department of Aube. The last zone here which corresponds to the blue-black clays of the Lower Albian with *Dowvilleiceras mammillatum* is characterised by *Citharina laffittei* Marie. This zone lies stratigraphically below the sulphur band at the base of the Gault at Folkestone. The foraminiferal zones of the Gault of Wissant (Pas-de-Calais) show greater similarity with the Gault of Folkestone than those of any other region. The following zones have been recognised here.

- I. *Textularia cretosa* Cushman, *Arenobulimina orbigny* (Reuss) — In all probability this latter species is *Arenobulimina macfadyeni* Cushman which is abundant at Folkestone and was previously described by Chapman (1892, p. 754) under the former name.
- III. *Citharinella pinnaeformis* (Chapman), *Vaginulina truncata* Reuss.
- IIIa. *Citharinella pinnaeformis* (Chapman), *Vaginulina truncata* Reuss, *Epistomina spinulifera* (Reuss)
- IIIb. *Citharinella pinnaeformis* (Chapman), *Citharinella karreri* (Berthelin), *Vaginulina truncata* Reuss, *Epistomina* sp., *E. spinulifera* (Reuss) and var., *Citharina arambourgi* Marie
- IVa. *Epistomina spinulifera* (Reuss) var., *Citharinella lemoinei* Marie
- IVb. *Citharinella lemoinei* Marie, *Lenticulina gaultina* (Berthelin)
- V. *Lenticulina gaultina* (Berthelin)

Zones IVa, IVb and V correspond respectively to PRICE's Beds VII and VI, V and IV, and I at Folkestone. Some of the species constituting these zones at Wissant have a more or less similar distribution at Folkestone, although they are not of zonal value here with the exception of *Epistomina spinulifera* (Reuss).





TABLE 2 (Continued)

SPECIES	Ammonite Sub-Zones	DUNTON GREEN								SEVENOAKS								
		dentalis spathi	intermedius				niobe		latus	Main Nodule bed	niobe				Sub-delaruel		Main Nodule Bed	
			D2	D3	D4	D5	D6	S1			S2	S3	S4	S5	S6	S7		
Planularia ingenua (Berthelin)	Sample No.	D1	-	-	-	-	-	-	D7	D8	-	-	-	-	-	-	-	S8
Marginulina acutirosta (Reuss)		V.R.	-	V.R.	V.R.	V.R.	-	-	V.R.	V.R.	V.R.	V.R.	V.R.	V.R.	-	-	-	-
Marginulina bronni (Roemer)		-	-	-	-	-	-	-	-	V.R.	-	-	-	-	-	-	-	-
Marginulina costulata (Chapman)		-	V.R.	V.R.	-	-	-	-	-	V.R.	-	-	-	-	-	-	-	-
Marginulina dubia Neugeboren		-	-	-	-	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-
Marginulina exilis (Reuss)		-	-	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-
Marginulina exilis (Reuss) var. crispata Chapman		-	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-
Marginulina glabra d'Orbigny		-	-	-	-	-	-	-	V.R.	-	-	-	-	-	-	-	-	-
Marginulina jonesi (Reuss)		V.R.	-	V.R.	V.R.	V.R.	-	V.R.	-	-	-	-	-	-	-	-	-	-
Marginulina lituola (Reuss)		-	-	-	V.R.	-	-	V.R.	-	-	-	-	-	-	-	-	-	-
Marginulina striata (Chapman)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marginulina striatocostata (Reuss)		-	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marginulina tenuissima (Reuss)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina communis d'Orbigny		-	-	-	-	V.R.	-	V.R.	-	-	-	-	-	-	-	-	-	-
Dentalina farcimen (Soldani)		-	-	-	-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina folkestoniensis (Chapman)		-	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina gracilis d'Orbigny		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina laxa Reuss		-	-	-	-	-	-	-	V.R.	-	-	-	-	-	-	-	-	-
Dentalina legumen Reuss		-	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina cf. legumen Reuss		-	V.R.	V.R.	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-
Dentalina roemerl Neugeboren		-	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina xiphoides Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentalina wimani Brotzen		-	-	-	-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-
Nodosaria bambusa Chapman		V.R.	-	V.R.	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-
Nodosaria fontannesi (Berthelin)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nodosaria fontannesi (Berthelin) var. flexo-carinata Khan		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nodosaria aff. loeblichae Dam		-	V.R.	V.R.	V.R.	V.R.	-	-	V.R.	-	-	-	-	-	-	-	-	-
Nodosaria obscura Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nodosaria orthopleura Reuss		V.R.	V.R.	V.R.	V.R.	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-
Nodosaria paupercula Reuss		-	V.R.	V.R.	V.R.	V.R.	-	-	V.R.	-	-	-	-	-	-	-	-	-
Nodosaria proboscidea Reuss		V.R.	-	V.R.	V.R.	V.R.	-	-	V.R.	-	-	-	-	-	-	-	-	-
Nodosaria radricula (Linn.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nodosaria radricula (Linn.) var. jonesi Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 2 (Continued)

[illegible]



TABLE 2 (Continued)

Ammonite Sub-Zones		DUNTON GREEN										SEVENOAKS									
SPECIES	Sample No.	dentatus spathi	intermedius					niobe		laetus	Main Nodule bed	intermedius			niobe		niobe ?	Sub-declatuei		Main Nodule Bed	
			D2	D3	D4	D5	D6	D7	D8			S1	S2	S3	S4	S5		S6	S7		S8
Frondicularia cordai Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Frondicularia gaultina Reuss		-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Frondicularia guestphalica Reuss		-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Frondicularia microdisca Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Frondicularia parkeri Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Frondicularia planifolium Chapman		-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Flabellinella chapmani (Marie)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Flabellinella pinnaeformis (Chapman)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lagena apiculata (Reuss)		V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lagena apiculata var. emaciata Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lagena hispida Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lagena sulcata (Walker and Jacob)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Globulina bucculenta (Berthelin)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Globulina prisca Reuss		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Glandulina laevigata (d'Orbigny)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ramulina aculeata Wright		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ramulina fusiiformis Khan		V.R.	-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ramulina globulifera Brady		-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ramulina globotubulosa Cushman		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bullopore laevis (Sollas)		V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bullopore tuberculata (Sollas)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bolvina subretacea Khan		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bolvina textilaroides Reuss		V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Siphonoceras asperula (Chapman)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Pleurostomella alternans Schwager		V.R.	-	V.R.	C	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	
Valvulineria parva Khan		A	F	C	V.A.	A	C	A	R	A	A	C	V.A.	V.A.	A	C	V.R.	V.R.	V.R.	V.R.	
Epistomina carpenteri (Reuss)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Epistomina elegans (d'Orbigny)		-	V.R.	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Epistomina spinulifera (Reuss)		V.R.	R	V.R.	-	-	-	-	V.R.	-	-	-	-	-	-	-	-	-	-	-	
Globigerina cretacea d'Orbigny		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Globigerina infracretacea Glaessner		-	V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Anomalina ammonoides (Reuss)		R	C	A	A	C	C	A	F	A	C	F	A	A	A	C	R	V.A.	V.R.	V.R.	
Anomalina complanata (Reuss) var. reussi Khan		A	A	A	A	C	F	A	F	V.A.	A	A	V.A.	V.A.	A	C	A	V.A.	V.A.	C	
Anomalina rudis (Reuss)		R	A	A	A	C	C	A	R	V.A.	A	A	V.A.	V.A.	A	C	A	A	A	F	

## APPENDIX

NOTE ON THE FORAMINIFERA  
FROM THE LOWER GAULT  
OF DUNTON GREEN AND SEVENOAKS

As would be expected, the foraminiferal fauna of Dunton Green and Sevenoaks is in its general aspect similar to that of Folkestone, but is poorer in quantity and number of species compared with the type locality. Except for the Miliolidae at Dunton Green and the Reophacidae and Cassidulinidae at both localities, all the families represented at Folkestone are present here, though the number of genera within each family and of species within each genus is much less. The family Lagenidae, as at Folkestone,<sup>1</sup> predominates over all other families both with regard to the number of genera and of species.

From Dunton Green 113 and from Sevenoaks 117 species and varieties have been identified. A comparison of the fauna of these localities with that of Folkestone shows that species which were known from Folkestone either by solitary specimens or very rarely, are those which have not been observed here.

An interesting feature is the striking difference between the Dunton Green-Sevenoaks and the Folkestone faunas in respect of the relative abundance of some species. For instance, *Bolivina textularioides* Reuss, *Epistomina elegans* (d'Orbigny), *E. carpenteri* (Reuss), *E. spinulifera* (Reuss) and *Globigerina infracretacea* Glaessner, which are 'flood forms' at Folkestone, are represented at Dunton Green and Sevenoaks only by a very small number of individuals. This may be due to local variations of environment.

The occurrence in the nodule bed at Sevenoaks of true *Globigerina cretacea* Orbigny is somewhat surprising as this species was neither observed at Folkestone nor at Dunton Green. Specimens previously referred to this species from the Gault of Folkestone, Red Chalk of Yorkshire and the Bargate beds of Surrey, belong to *G. infracretacea* Glaessner. This is perhaps the first record as far as is known of the occurrence of true *G. cretacea* Orbigny in the Lower Cretaceous of England.

1. The present writer has in preparation a revision of the foraminifera from the Lower Gault of Folkestone.

In the accompanying Table 2 the relative distribution of species from Dunton Green and Sevenoaks is given. The legend is as follows. Very rare = from 1-5 specimens; rare = 5-10; frequent = 10-20; common = 20-30; abundant = 30-50; and very abundant = above 50.

## REFERENCES

- CHAPMAN, F., 1892. Foraminifera of the Gault of Folkestone. part 3. Jour. Roy. Micr. Soc., London.
- EICHENBERG, W., 1935. Mikrofaunen-Tafeln zur Bestimmung von Unterkreide-Horizonten in Bohrkernen norddeutscher Oelfelder. Oel und Kohle, vol. 2, pt. 23.
- HECHT, F. E., 1938. Standard-Gliederung der nordwestdeutschen Unterkreide nach Foraminiferen-Senckenbergische Naturforschende. Gesellschaft. Abh. 443.
- KHAN, M. H., 1950. On some New Foraminifera from the Lower Gault of Folkestone, Dunton Green and Sevenoaks. Jour. Roy. Micr. Soc., London. ser. 3, vol. 70, pt. 3, pp. 268-279, pls. I-II.
- MARIE, P., 1939. Zones à Foraminifères du Crétacé Moyen de Saint-Florentin (Yonne). C. R. S., Soc. Géol. France, no. 11.
- , 1941. Zones à Foraminifères du Gault dans le Département de l'Aube. l. c., no. 8.
- , 1941a. Zones à Foraminifères des marnes du Gault de Wissant (Pas-de-Calais). l. c., no. 10.
- , 1941b. Zones à Foraminifères du Gault atteintes par forage dans la région parisienne. l. c., no. 15.
- , 1941c. Sur la microfaune des argilles Albiniennes du Pays de Bray. l. c., no. 12.
- PRICE, F. G. H., 1874. On the Gault of Folkestone. Quart. Jour. Geol. Soc., London. vol. 30.
- SPATH, L. F., 1923-43. A Monograph of the Ammonoidea of the Gault. Vol. I and II. Mong. Palaeont. Soc., London.
- WRIGHT, C. W. and H. D. THOMAS, 1946. Notes on the Geology of country round Sevenoaks, Kent. Proc. Geol. Assoc. London. vol. 57, part. 4.

61. FORAMINIFERA DISTRIBUTION IN SOME SEDIMENT SAMPLES  
FROM THE CANADIAN AND GREENLAND ARCTIC

FRED B PHLEGER

## SUMMARY

1. - Foraminifera populations have been analyzed in 49 bottom sediment samples from the Greenland and Canadian Arctic from approximately 70° N. Lat. to 80° N. Lat. and from 59° W. Long. to 112° W. Long.

2. - Planktonic Foraminifera are present at only one-third of the stations, and consist principally of *Globigerina pachyderma* (Ehrenberg) with smaller populations of *G. bulloides* Orbigny and juvenile globigerinids.
3. - The benthonic Foraminifera-fauna is a character-



istic Arctic assemblage, is essentially uniform throughout the region, and is dominated by the following species:

*Cassidulina norcrossi* Cushman  
*Cibicides lobatulus* (Walker and Jacob)  
*Elphidium incertum* (Williamson) and vars.  
*Eponides frigidus* (Cushman)  
*Haplophragmoides glomeratum* (Brady)  
*Proteonina atlantica* Cushman  
*Spiroplectammina biformis* (Parker and Jones)  
*Textularia torquata* Parker (Ms.).  
*Trochammina nana* (Brady)

4. - There are indications of depth zonation in Baffin Bay, Lancaster Sound, Melville Sound, and at some of the shallow-water harbor areas. Mixing of faunas is attributed to ice-rafting. It is suggested that the occurrence of considerable quantities of shallow-water sedimentary materials transported into deep water by ice-rafting and there mixed with sediments more normal to this zone may be one of the main characteristics of Arctic marine sediments.
5. - It is demonstrated that the faunas from different parts of this region can be distinguished from each other.

### INTRODUCTION

The Foraminifera discussed in this paper are from 49 marine sediment samples collected by members of the United States Coast Guard aboard the USS NORTHWIND during the summer of 1947. All the samples are from the Canadian and Greenland Arctic, and are within a region extending from approximately 71° N. Lat. to 80° N. Lat. and 59° W. Long. to 112° W. Long. The purposes of the present study are as follows:

- 1.) to record in quantitative terms the Foraminifera populations in samples taken from a region where the Foraminifera are little known, and
- 2.) to analyze any general geographic variations or similarities which may exist in these populations.

The writer acknowledges with gratitude the cooperation of the U. S. Coast Guard and the captain of the USS NORTHWIND in collecting the samples and making them available for study. Much of the work in studying this material has been done by Frances L. Parker and Jean F. Peirson. The laboratory work has been financed by the Office of Naval Research under Project NR 081 050.

### METHODS

Twenty-one of the samples were collected using a dwarf orange-peel dredge having a rated capacity of 100 cu. in. The dredge was covered with a canvas hood to prevent washing of the sediment sample enroute to the surface. It was further modified with a tripping device so that it can be operated from one wire in place of the two wires usually employed. A representative portion for laboratory study was saved

from the relatively large sample collected with this instrument.

Eighteen samples were collected with the bottom sediment sampler designed by Phleger (1951). This gear obtains a short core emplaced in a plastic tube and recovers material from a known and constant area of the actual surface of the bottom in a relatively undisturbed condition. The surface sediment in the short cores was treated with formaldehyde to preserve the living population of Foraminifera.

The fauna from a thickness of 1 cm. of the top of each core was studied. The presence of Foraminifera which were alive when the sample was collected was determined by the biuret test for protein as follows: The bottom sample is washed over a #200 brass sieve until it is free from mud and is then placed in a test tube with a small amount of water. An approximately equal amount of 10% sodium hydroxide is added and the solution is allowed to stand for 10 minutes. 30 to 60 drops of 0.5% copper sulfate solution are added, with vigorous agitation of the solution after each 3-5 drops. The solution is placed in a petri dish marked off with a grid pattern. Protoplasm, colored purple or pink, is best seen against a white background with a properly adjusted light source.

After examination for living specimens the sample is thoroughly washed and dried, and the population in the dry sample is studied. Counts are made of the species and either the entire population is counted or a total population estimate is made from the count of a fraction of a large sample.

### DISTRIBUTION OF SPECIES

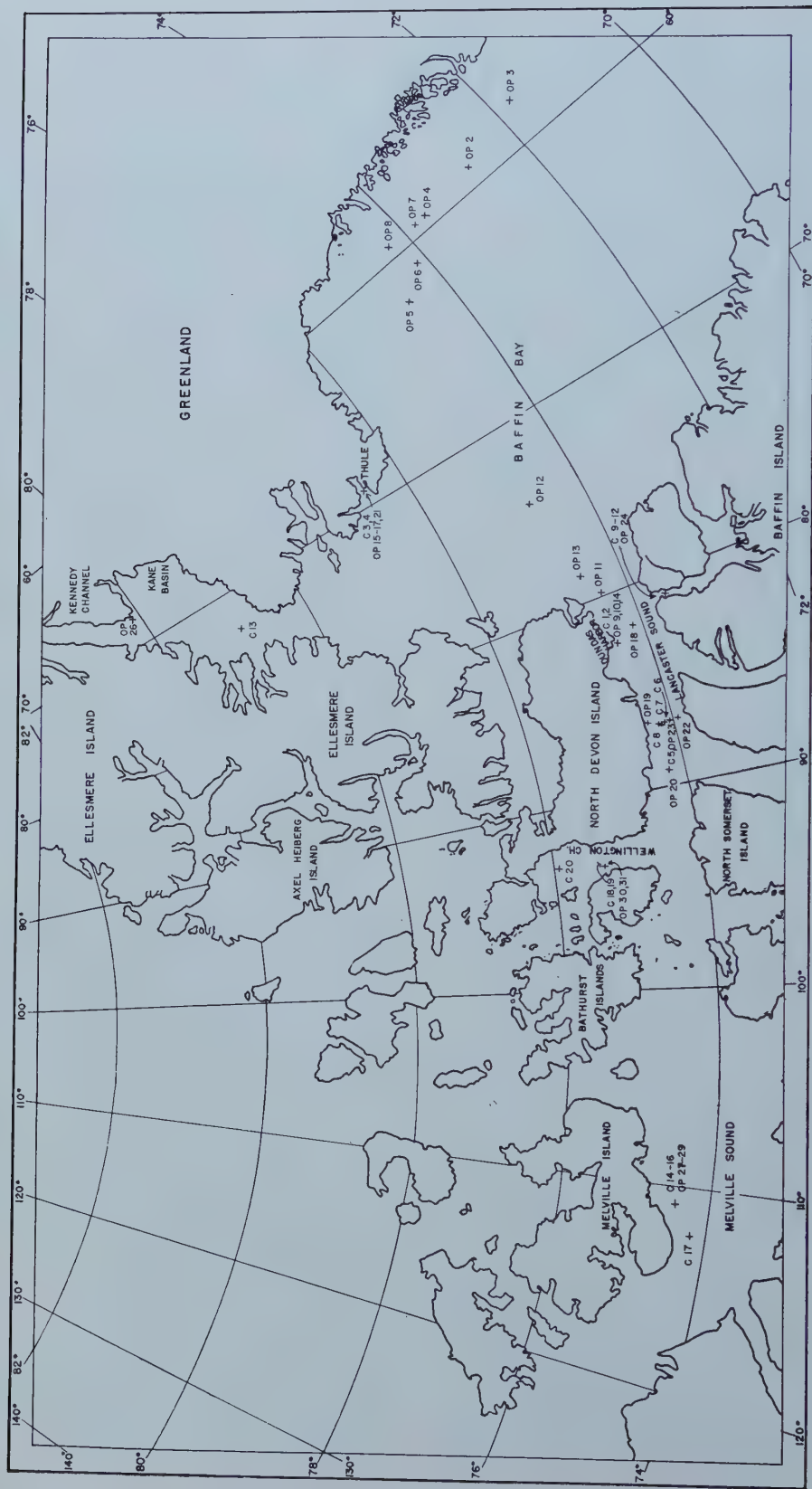
#### PLANKTONIC FORAMINIFERA

Planktonic Foraminifera are recorded from 18 of the stations in low frequencies except at station C 3 where there is an estimated population of approximately 2500 specimens. The most common species is *Globigerina pachyderma* (Ehrenberg), a typically Arctic and sub-Arctic form. *Globigerina bulloides* Orbinny is the only other recognizable planktonic species. Unidentifiable young *Globigerina* occurs at several stations.

#### BENTHONIC FORAMINIFERA

The assemblage of benthonic Foraminifera consists of at least 45 species which occur in significant abundance at several stations. The benthonic fauna for the region as a whole is dominated by the following species, listed in alphabetical order:

*Cassidulina norcrossi* Cushman  
*Cibicides lobatulus* (Walker and Jacob)  
*Elphidium incertum* (Williamson) and vars.  
*Eponides frigidus* (Cushman)  
*Haplophragmoides glomeratum* (Brady)  
*Proteonina atlantica* Cushman  
*Spiroplectammina biformis* (Parker and Jones)  
*Textularia torquata* Parker (Ms.)  
*Trochammina nana* (Brady)



Text Fig. 1. CHART SHOWING THE LOCATIONS OF THE STATIONS



The distribution chart of species appears as Table 1; individual species distributions are discussed below.

*Ammobaculites cassis* (Parker). At only 7 stations in frequencies usually less than 2%, except at one station in Toy Bay where it is 24% of fauna. Most occurrences in Dundas Harbor and Burnett Creek, but also present in 1 sample each in Baffin Bay, Lancaster Sound and Toy Bay.

This species is reported in the Atlantic from Barnstable, Mass., and from off Portsmouth, N. H., but the specimens are not typical. It also occurs in the Pacific, according to Cushman, from north of the New Siberian Islands in the Russian Arctic, off Nova Zembla, and from off Alaska in very shallow water. It is probably a very shallow-water form, usually occurring at less than about 20 fathoms.

*Ammodiscus gullmarensis* Höglund. Frequencies up to 6% but usually 1% or less. Occurs at most stations in Thule and Lancaster Sound, and present at 1 station in Baffin Bay, 2 stations in Wellington Channel, and 3 stations in Melville Sound.

Höglund has reported this species from Gullmar Fjord, off Sweden, at 24-79 meters.

*Angulogerina angulosa* (Williamson). Usual frequencies 5% or less but 10% at one Thule station. Not present in Dundas Harbor, Toy Bay, and Melville Sound.

This species is widespread in the Atlantic. It is abundant off the northeast coast of the U. S., but probably does not occur south of Cape Hatteras. It has no facies significance according to Parker (1948). It is reported as rare in the Antarctic but abundant around the Falklands; occurs at numerous stations between Alaska and the Guadalupe Islands.

*Astrononion stellatum* Cushman and Edwards. Frequencies 5% or less and occurs at numerous stations except in Toy Bay.

This species is widely distributed in the colder parts of the North Atlantic. It is reported from off Newfoundland, Iceland, and from the southwest Gulf of Maine. It does not occur south of Cape Cod.

*Bolivina pseudopunctata* Höglund. 4% or less in Lancaster Sound, Dundas Harbor, and Wellington Channel, with one occurrence at Thule.

Previously reported from Gullmar Fjord at 26-118 m., and the Skagerrak deeper than 500 m. It is present in the Portsmouth, N. H. area at 4 shallow stations.

*Cassidulina islandica* Nørvang var. *minuta* Nørvang.<sup>1</sup> Common at many stations throughout the region ex-

cept in Toy Bay and 1 occurrence only in Melville Sound. Highest frequencies in Dundas Harbor, up to 33%.

This species is rare off Portsmouth, N. H., in the southwest Gulf of Maine, and has been reported from off Iceland.

*Cassidulina norcrossi* Cushman. High frequencies at most stations except Toy Bay and only 1 occurrence in Melville Sound, with greatest abundance at Thule, Dundas Harbor, and Wellington Channel (up to 43%).

This species is reported previously from off Greenland and Iceland. On the continental shelf of the western Atlantic it reaches its greatest frequency below 300 m.

*Cibicides lobatulus* (Walker and Jacob). Abundant at many stations and generally distributed throughout the area. Highest frequency in Kane Basin (61%), with frequencies up to 25% at some stations in Lancaster Sound, Dundas Harbor, and Wellington Channel.

This is a very widespread attached form, probably characteristic of shallow water.

*Criboelphidium bartletti* (Cushman). Only known from 2 stations in Dundas Harbor and 1 station at Burnett Creek, with frequencies up to 12%.

This species is reported from Puget Sound by Cushman and Todd. Many of the specimens reported from the Arctic as *Nonion orbiculare* may belong here.

*Discorbis* sp. Principal occurrence in Dundas Harbor at 2% or less. 1% or less at 1 station in Kane Basin and Wellington Channel, and at 2 stations in Lancaster Sound.

*Elgerella advena* (Cushman). Principally restricted to Dundas Harbor and Thule but present at 1 station in Baffin Bay, Lancaster Sound and Burnett Creek. Highest frequencies are at Thule where they range from 12% to 50%.

This species occurs around the British Isles, off Scandinavia, and occurs shallower than 90 m. in the western Atlantic. It is also present in the Portsmouth, N. H. area, rarely in the Antarctic, and is present in the eastern Pacific from Alaska to Peru.

*Elphidiella arctica* (Parker and Jones). Occurs at 6 stations with frequencies of 4% or less; 1 station in Baffin Bay, 1 in Kane Basin, 1 at Dundas Harbor, and 3 stations in Wellington Channel.

This species is previously reported from Hudson Bay, Iceland, and off the New England coast. It is not reported from the Antarctic.

*Elphidium incertum* (Williamson) and vars. Generally distributed except in Toy Bay and Melville Sound. Highest frequencies in Dundas Harbor, Burnett Creek, and Wellington Channel, ranging up to 25%. Less abundant (where it occurs) in other areas.

This species is widely distributed in the Arctic and North Atlantic.

<sup>1</sup> Note by Editor: *Cassidulina islandica* Nørvang, 1945, forma *minuta* Nørvang, 1945, The Zool. of Iceland, vol. 2, pt. 2, p. 43, text figs. 8a-c. Recent, off Iceland, regarded as a true variety (or subspecies) by Cushman, 1948, Cushman Lab. Foram. Research, Spec. Publ. No. 23, p. 75-76, is a homonym of *Cassidulina minuta* Cushman, 1933, Cushman Lab. Foram. Research, Contr., vol. 9, p. 92, pl. 10, fig. 3. Recent, Tropical Pacific, and herewith renamed: *Cassidulina islandica* Nørvang, 1945, var. *nørvangi* Thalmann, nom. nov.

LOCATION	BAFFIN BAY	THULE	KENNEDY CHANNEL	LANCASTER SOUND	DUNDAS HARBOR	TOY BAY	BURNETT CREEK	WELLINGTON CHANNEL	MELVILLE SOUND
NORTH LATITUDE	72°48'	74°16'	78°53'	74°18'	74°13'	73°37'	73°37'	74°23'	74°15'
WEST LONGITUDE	58°30'W	68°48'W	67°42'W	67°42'W	67°42'W	67°42'W	67°42'W	67°42'W	67°42'W
SAMPLE	188	188	188	188	188	188	188	188	188
DEPTH IN METERS	16	16	16	16	16	16	16	16	16
TOTAL PLANKTONIC POPULATION	16	16	16	16	16	16	16	16	16
Globigerina bulloides	12	12	12	12	12	12	12	12	12
G. pachyderma	87	87	87	87	87	87	87	87	87
G. sp.									
TOTAL BENTHONIC POPULATION	900	900	900	900	900	900	900	900	900
Ammobaculites cassis	3	3	3	3	3	3	3	3	3
Ammobaculites gullmoresensis									
Angulogerina angulosa	2	2	2	2	2	2	2	2	2
Astrononion stellatum	1	1	1	1	1	1	1	1	1
Bolivina pseudopunctata									
Cassidulina islandica minuta	6	6	6	6	6	6	6	6	6
C. norcrossi	8	8	8	8	8	8	8	8	8
Cibicides lobatulus	14	14	14	14	14	14	14	14	14
Criboelphidium bartletti									
Discorbis sp.									
Eggerella advena	13	13	13	13	13	13	13	13	13
Elphidium arctica	4	4	4	4	4	4	4	4	4
Elphidium incertum & variants	2	2	2	2	2	2	2	2	2
E. subarcticum	4	4	4	4	4	4	4	4	4
Eponides frigidus	5	5	5	5	5	5	5	5	5
Globobulimina ariculata arctica	7	7	7	7	7	7	7	7	7
Haplophragmoides glomeratum	32	32	32	32	32	32	32	32	32
Labrosipira arctica	1	1	1	1	1	1	1	1	1
L. crassimargo	2	2	2	2	2	2	2	2	2
L. jeffreysi	1	1	1	1	1	1	1	1	1
Lagenidae, etc.									
Miliammina groenlandica	2	2	2	2	2	2	2	2	2
Nonion barleeanum	1	1	1	1	1	1	1	1	1
N. labradoricum	1	1	1	1	1	1	1	1	1
Oolina costata									
Proteonina atlantica	10	10	10	10	10	10	10	10	10
Psammospira fusca									
Recurviroides turbinatus	6	6	6	6	6	6	6	6	6
Reophax arctica	10	10	10	10	10	10	10	10	10
R. curtus	1	1	1	1	1	1	1	1	1
R. guttifera									
R. nodulosa									
R. cf. scapularis									
Spiroplectammina bifurcata	2	2	2	2	2	2	2	2	2
Textularia tenuissima	5	5	5	5	5	5	5	5	5
T. torquata	2	2	2	2	2	2	2	2	2
Trochammina inflata									
T. nana	7	7	7	7	7	7	7	7	7
T. quadriloba									
T. squamata									
Trochammina atlantica	4	4	4	4	4	4	4	4	4
T. bullata									
Virgulina cf. complanata	3	3	3	3	3	3	3	3	3
V. fusiformis	3	3	3	3	3	3	3	3	3

Table 1. Occurrences of Foraminifera in the samples given in percent of total population at each station.

*Cassidulina islandica minuta* has been renamed: *Cassidulina islandica* Nørvang var. *nørvangi* Thalmann (see p. 83, footnote 1).

*Textularia tenuissima* will be renamed *Textularia earlandi* by F. L. Parker in a forthcoming paper.

*Elphidium subarcticum* Cushman. Essentially the same distribution as the *E. incertum* group but the frequencies are lower, generally less than 10%, and none greater than 13%.

Occurs off Portsmouth, N. H., and in Long Island Sound in shallow water and at all depths on the Atlan-

tic continental shelf and upper continental slope. It is reported from the Arctic by Cushman.

*Eponides frigidus* (Cushman). Common at most stations with frequencies up to 10% but usually less. Not present at Toy Bay and Melville Sound and at only 3 stations in Baffin Bay.



Present in shallow-water facies off Portsmouth, N. H., and in the open-ocean facies in Long Island Sound area. Also reported from Hudson Bay, Iceland, Gaspé Bay, and from all facies on the Atlantic continental shelf.

*Globobulimina (Desinobulimina) auriculata* (Bailey) var. *arctica* Höglund. At 1 station in Baffin Bay and 1 station in Lancaster Sound, at less than 1%.

This variety is reported from Spitzbergen, Greenland, and Baffin Bay.

*Haplophragmoides glomeratum* (H. B. Brady). Abundant at the majority of stations but does not occur in Toy Bay and Burnett Creek, and only 1 specimen in Dundas Harbor. Average frequencies 20% or more but 1% or less at a few stations. Lowest frequencies in Wellington Channel.

Reported from the Arctic, North Atlantic, and Gulf of Mexico. Widespread off Portsmouth, N. H., but not so abundant near shore.

*Labrospira arctica* Parker. At 4 stations, at 2% or less, in Baffin Bay, and 1 specimen from Dundas Harbor. This species is being described by Parker elsewhere.

*Labrospira crassimargo* (Norman). In all areas except Toy Bay and Burnett Creek with frequencies varying from less than 1% to 20%. Most abundant in Melville Sound where it occurs at all stations in relatively high frequencies.

This species has been reported from numerous areas as *Haplophragmoides major* Cushman. It is widely distributed off Portsmouth, N. H., is reported from Eastport, Me., the Grand Banks area, an open-ocean facies near Long Island Sound, the British Isles, and from the Antarctic. It is probably widespread in the Arctic. Höglund reports it from the Gullmar Fjord and the Skagerrak, where it ranges from 55 m. to 300 m. water depth.

*Labrospira jeffreysii* (Williamson). At the majority of stations in all areas except Toy Bay, with usual frequencies 5% or less.

Widely distributed off Portsmouth, N. H., and reported from off Eastport, Me., and from east of Cape Cod but not farther south. It is probably widespread in the Arctic, and some reports of *Haplophragmoides canariensis* Orbigny from shallow stations in the Antarctic by Earland and also Chapman and Parr may belong here. Also reported from the Gullmar Fjord and the Skagerrak.

*Lagenidae*. Usual frequencies 1% or less but up to 4% at a few stations. In all areas except Toy Bay, Burnett Creek, and Melville Sound, and at only 1 station in Baffin Bay.

*Miliammina groenlandica* Cushman. At 1 station at Thule, 1 station in Baffin Bay, the majority of stations

in Lancaster Sound, 1 station in Dundas Harbor, and 3 stations in Wellington Channel, with frequencies of 2% or less. About 30% of the fauna at 2 stations in Toy Bay.

Previously reported from Iceland and other Arctic areas.

*Nonion* sp. cf. *N. barleeianum* (Williamson). At the majority of stations in Baffin Bay, Kane Basin, Kennedy Channel, and Lancaster Sound. At 2 stations at Thule, 1 station in Dundas Harbor, and 1 station in Melville Sound. Usual frequencies 3% or less except at 2 stations in Baffin Bay where frequencies are more than 10%.

Widely distributed in the North Atlantic.

*Nonion labradoricum* (Dawson). At most stations at Thule, Lancaster Sound, Dundas Harbor, and Wellington Channel. Also at 2 stations in Baffin Bay and 1 station in Toy Bay. Frequencies are 8% or less.

This species appears to be widespread in the western North Atlantic with the greatest abundance in the more northern areas.

*Oolina costata* (Williamson). At 3 stations in Wellington Channel and 1 station in Kane Basin. Frequencies less than 1%.

*Proteonina atlantica* Cushman. Widely distributed at majority of stations in frequencies generally less than 10% but as great as 19%. Not present at Burnett Creek and Kennedy Channel.

Appears to be widespread in the North Atlantic; sometimes reported as *P. difflugiformis* Brady.

*Psammosphaera fusca* F. E. Schultze. Present only in Melville Sound in frequencies up to 6%.

Widely distributed in the Arctic, according to Cushman, and also reported from off Norway.

*Recurvoides turbinatus* (H. B. Brady). Present at numerous stations in all areas except Kane Basin, Kennedy Channel, Toy Bay, and Burnett Creek. Frequencies 4% or less.

This species is very common off Portsmouth, N. H., and is reported by Parker from the Atlantic continental shelf. Earland records it as rare in the Antarctic.

*Reophax arctica* H. B. Brady. At the majority of stations in all areas except Burnett Creek, Kane Basin, and Kennedy Channel. Frequencies up to 10%.

Present in the Gulf of Maine but not reported south of Cape Cod.

*Reophax curta* Cushman. At a few stations in all areas except Kennedy Channel, Toy Bay, and Burnett Creek. Frequencies up to 4%.

This species is reported from the British Isles, the Arctic, Gulf of Maine, and the open-ocean facies near Long Island Sound. It may be present in the Antarctic.

*Reophax guttifera* H. B. Brady. At 2 stations in

Baffin Bay and 2 stations in Melville Sound. Frequency up to 6%.

Appears to be widespread in the Atlantic, according to published reports. Reported from Spitzbergen.

*Reophax nodulosa* H. B. Brady. Occurs in all samples in Melville Sound with frequencies up to 4%. No other occurrences noted in samples studied.

This species has a wide distribution in deep water, according to Brady.

*Reophax* sp. cf. *R. scorpiurus* Montfort. At majority of stations in Melville Sound and at 7 other widely distributed stations. Frequency up to 10%.

*Spiroplectammina biformis* (Parker and Jones). Generally common throughout the region but not recorded from Kane Basin or Kennedy Channel. Average frequencies up to about 10%, but may be more than 50%. The dominant species in Toy Bay.

This species has a wide distribution in Arctic and sub-Arctic areas. It is very abundant in the Gulf of Maine off Portsmouth, N. H., and very rare south of Cape Cod. It is previously reported from off Greenland, Davis Strait, Gulf of St. Lawrence, the British Isles, Franz Josef Land, the Russian Arctic, and off the coast of Washington. It is reported as rare in the Antarctic.

*Textularia earlandi* Parker (Ms.).<sup>2</sup> At approximately half the stations, but not present in Dundas Harbor, Toy Bay or Burnett Creek. Frequencies up to 50%.

Reported by Earland as rather widespread in the

Antarctic and also present around the Falklands. Chapman and Parr report it as rare in a few of their Antarctic samples. It is abundant in the Skagerrak and Kattegat. Reported from the Mediterranean.

*Textularia torquata* Parker (Ms.). Abundant at the majority of stations with frequencies as high as 40%.

Common off Portsmouth, N. H., where it is described.

*Trochammina conica* Earland. Only 1% at station C 16, and the first time reported from outside the Antarctic.

*Trochammina inflata* (Montagu). At 4 stations in Melville Sound and 1 station in Dundas Harbor with frequencies of 2% or less.

This species is a brackish water indicator on Cape Cod, Long Island Sound, and elsewhere. It is recorded from both sides of the Atlantic and from the Pacific from Alaska to Ecuador.

*Trochammina nana* (H. B. Brady). Abundant at most stations in Baffin Bay, Lancaster Sound, and Melville Sound with frequencies up to 50% or more. At 4 stations at Thule with frequencies up to 10%. At 1 station in Dundas Harbor and 3 stations in Wellington Channel with frequencies less than 1%. Not found in Toy Bay, Burnett Creek, or Kane Basin.

This species is reported as widespread in the Arctic and Antarctic.

*Trochammina quadriloba* Höglund. At 5 stations in Lancaster Sound with a frequency up to 17%. Also at 1 station at Thule and 1 station in Baffin Bay.

Occurs at numerous stations in the southwest Gulf of Maine and also reported off Sweden.

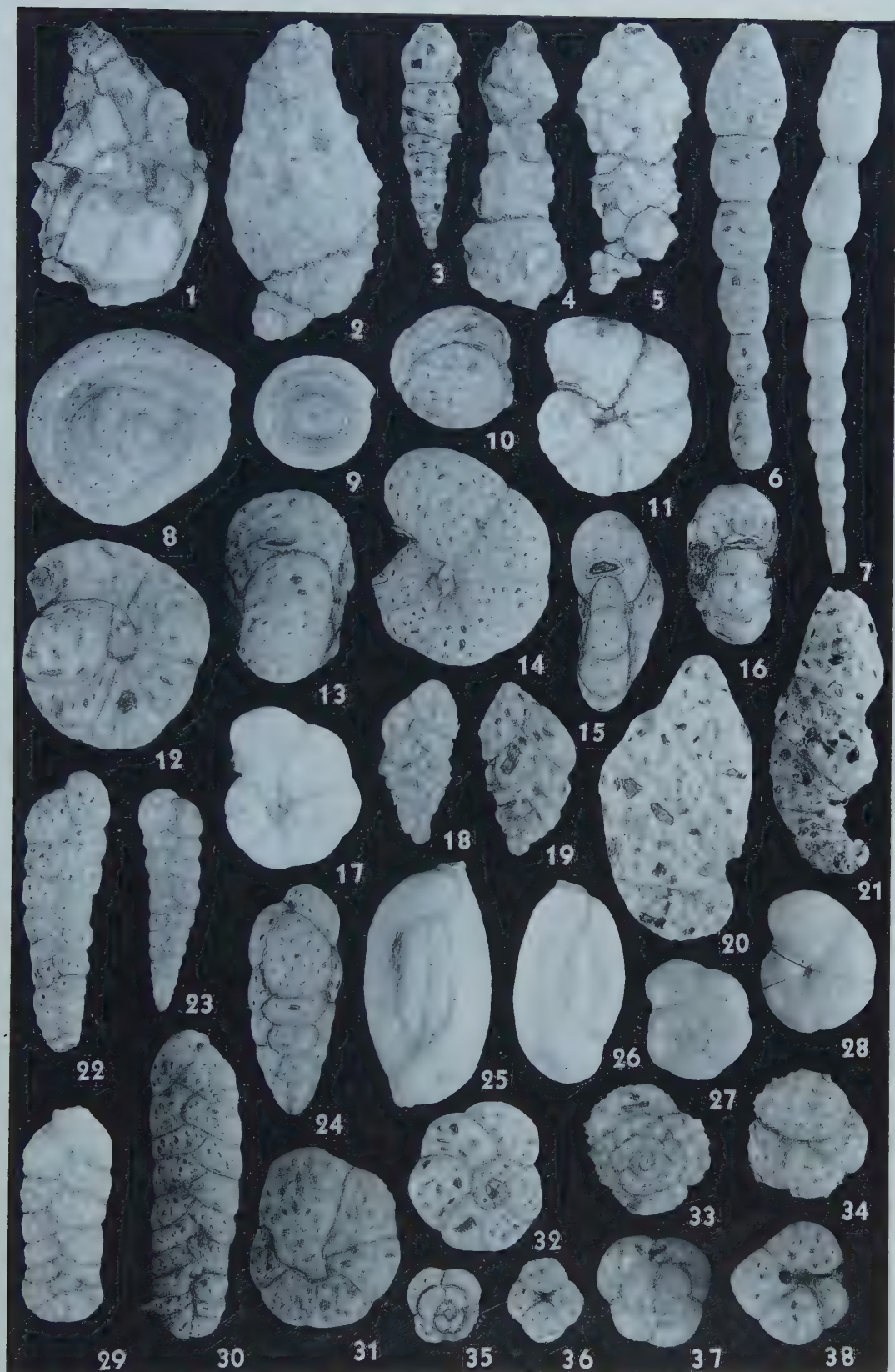
*Trochammina squamata* Parker and Jones. At 1 sta-

<sup>2</sup> This manuscript name, *Textularia earlandi* Parker, will shortly be published on account of homonymy of *Textularia tenuissima* Earland, 1933, *Discovery Repts.*, vol. 7, p. 95, pl. 3, figs. 21-30, Recent, Antarctic, off South Georgia, with *Textularia tenuissima* Häusler, 1881, Diss. (Thesis), Univ. Zurich, p. 40, pl. 2, fig. 75, Sequanian, Switzerland. (Editor's note).

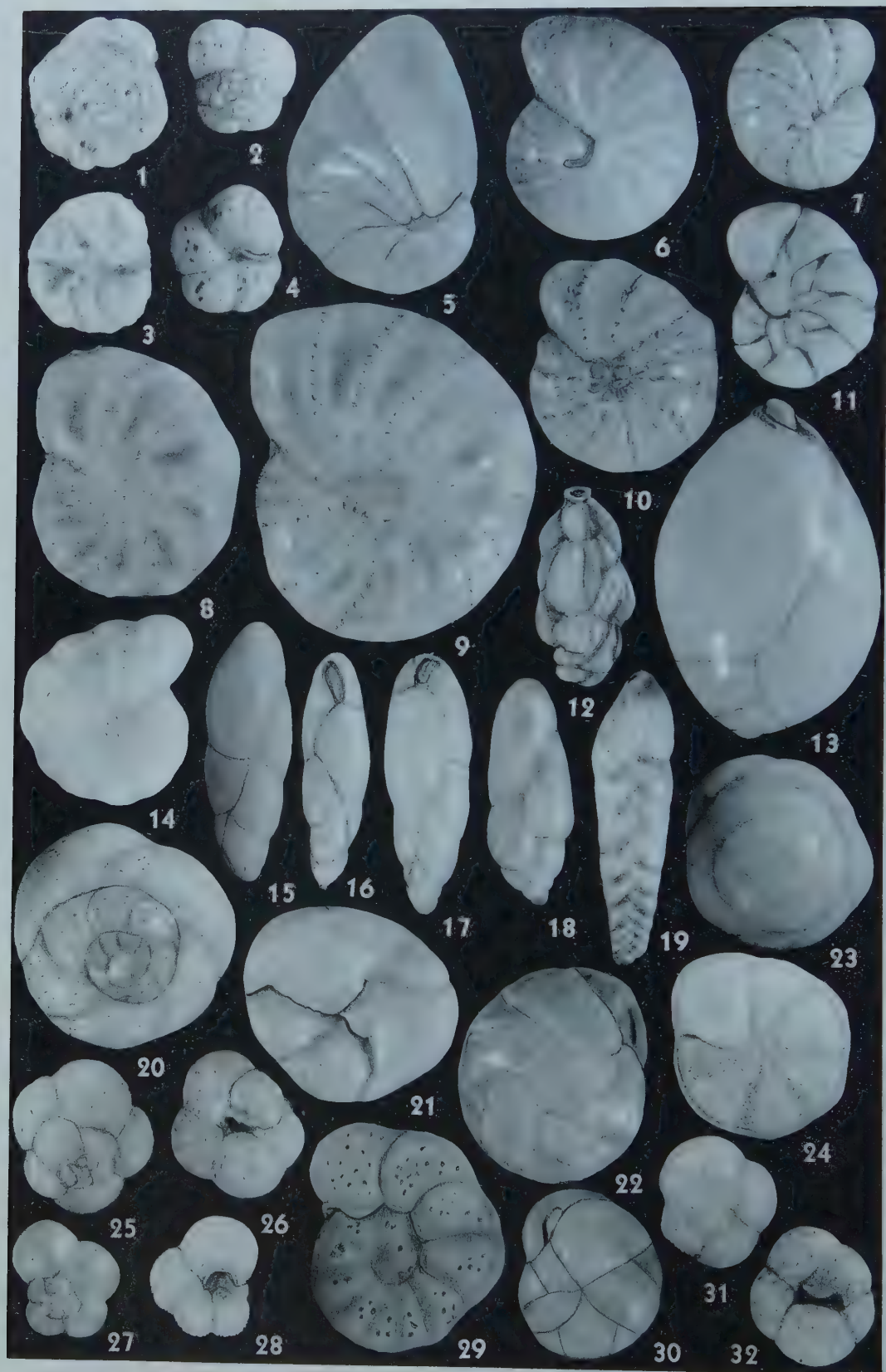
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Phleger, Canadian and Greenland Arctic Foraminifera



Phleger, Canadian and Greenland Arctic Foraminifera



tion in Baffin Bay, 3 stations at Thule, and 1 station in Dundas Harbor. 1% or less of the fauna.

This species is abundant in the southwest Gulf of Maine. It is previously recorded from the Arctic, Davis Strait, and from deep-water Atlantic samples.

*Trochammina atlantica* Parker. At most stations in Melville Sound, 1 station in Wellington Channel, 1 station in Lancaster Sound, and 3 stations in Baffin Bay. Up to 80% of the fauna where present.

*Trochammina bullata* Höglund. At 2 stations in Baffin Bay with frequencies up to 14%, 2 stations in Lancaster Sound at less than 10%, 1 station in Wellington Channel at less than 10%, and 2 stations in Melville Sound with a frequency at 1 station of 24%.

Previously reported from the Skagerrak.

*Virgulina* sp. cf. *V. complanata* Egger. Most common in Lancaster Sound at 4% or less. Also present at 1 station in Baffin Bay, at Kane Basin, Kennedy Channel, and at 2 stations in Wellington Channel.

*Virgulina fusiformis* (Williamson). At all stations in Dundas Harbor, Wellington Channel, and Burnett Creek with frequencies up to 27%. Also at 1 station in Baffin Bay, 3 stations at Thule, 2 stations in Lancaster Sound, and 1 station in Melville Sound at 3% or less of the fauna.

This species is reported from the southwest Gulf of Maine, from the Atlantic continental shelf, the British Isles, and off Sweden.

#### LIVING BENTHONIC FORAMINIFERA

The surface sediment of the core samples was treated with formaldehyde for identification of specimens which were alive when the samples were collected. Living specimens were identified from about half of

the core samples. Living specimens were most abundant in Lancaster Sound where they were present in significant abundance in all core samples. They are recorded also from all stations in Wellington Channel and from 1 station at Thule and 1 station in Dundas Harbor.

*Proteonina atlantica* Cushman was the most common living species; in addition, specimens of the following also were identified:

*Angulogerina angulosa* (Williamson)

*Cassidulina islandica* Nørvang var. *minuta* Nørvang

*Cibicides lobatulus* (Walker and Jacob)

*Elphidium subarcticum* Cushman

*Eponides frigidus* (Cushman)

*Globobulimina auriculata* (Bailey) var. *arctica* Höglund

*Haplophragmoides glomeratum* (Brady)

*Labrospira crassimargo* (Norman)

*Nonion barleeianum* (Williamson)

*N. labradoricum* (Dawson)

*Reophax* sp. cf. *R. scorpiurus* Montfort

*Trochammina nana* (Brady)

This is the approximate percentage representation of living species usually found in a fauna sampled by the methods used and with this frequency of sampling. It is believed that living specimens would have been discovered of all species recorded if sufficient material had been collected and examined.

#### INTERPRETATION OF FAUNAS

The number of sediment samples collected is insufficient for any definitive study of microfaunal distributions in so large an area. The faunas are so relatively consistent for the region as a whole, however, that the

#### EXPLANATION OF PLATE 14

Figs.		PAGE
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10.	<i>Elphidium incertum</i> (Williamson) var. <i>clavatum</i> Cushman. × 68. OP 10. ....	83
11.	<i>Astrononion stellatum</i> Cushman and Edwards. × 68. OP 15. ....	83
12.	<i>Angulogerina angulosa</i> (Williamson). × 94. OP 21. ....	83
13.	<i>Globobulimina</i> ( <i>Desinobulimina</i> ) <i>auriculata</i> (Bailey) var. <i>arctica</i> Höglund. × 68. OP 2. ....	85
14.	<i>Elphidiella arctica</i> (Parker and Jones). × 28. Core 13. ....	83
15, 16.	<i>Virgulina</i> sp. cf. <i>V. complanata</i> Egger. × 94. (15) OP 2; (16) Core 13. ....	87
17, 18.	<i>Virgulina fusiformis</i> (Williamson). × 94. OP 9. ....	87
19.	<i>Bolivina pseudopunctata</i> Höglund. × 94. OP 9. ....	83
20, 21.	<i>Discorbis</i> sp. × 68. Core 13. ....	83
22.	<i>Cassidulina norcrossi</i> Cushman. × 68. OP 31. ....	83
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30.	<i>Cassidulina islandica</i> Nørvang var. <i>nørvangi</i> Thalmann, nom. nov. × 94. OP 9. ....	83
31, 32.	<i>Globigerina pachyderma</i> (Ehrenberg). × 68. OP 26. ....	81

results are believed to be more reliable than sample distribution and intensity would suggest. The data and interpretations presented may be modified by study of additional material, but it is believed that the major features of the distributions are essentially correct.

There is a suggestion of some depth zonation in this region, but this is confused by what appears to be faunal mixing of shallow and deep-water sediments. Probable depth zonation is more apparent in Baffin Bay than in Lancaster Sound, the only two areas from which there are samples having a significant depth range. In Baffin Bay the following species appear to be generally indicative of water depths less than about 250 m.:

- Angulogerina angulosa* (Williamson)
- Astrononion stellatum* Cushman and Edwards
- Cassidulina islandica* Nørvang var. *minuta* Nørvang
- Cassidulina norcrossi* Cushman
- Cibicides lobatulus* (Walker and Jacob)
- Elphidiella arctica* (Parker and Jones)
- Elphidium incertum* (Williamson) and vars.
- Eponides frigidus* (Cushman)
- Miliammina groenlandica* Cushman

In general these species show no similar depth restriction in Lancaster Sound, where the depths are somewhat greater, although *Elphidium* is not reported from this area. In Melville Sound there is one relatively deep sample (409 m.) which has a significantly different fauna from the other samples in the area which are from 124 m.

Considerable faunal mixing is obvious in the samples and it is suggested that this is caused by ice-rafting. Faunal mixing and thus absence of clearcut depth zonation may be a characteristic of Arctic areas, especially those areas in which there is considerable shallow water around an intricate coastline. Ice transportation of sedimentary materials, including Foraminifera from near shore zones and later deposition in deeper waters is probably one of the main sedimentary processes in Arctic and Antarctic regions.

The distribution of Arctic Foraminifera has been little studied, and it is not possible to compare the present fauna with others from the Arctic. It is believed that faunas from this region can be differentiated from other Arctic faunas, but it will be necessary to study a great deal of additional material from widely distributed areas before there can be any certainty of this. The present fauna appears to be related to the assemblage near Iceland by having the following species reported from these two regions:

- Cassidulina norcrossi* Cushman
- Cassidulina islandica* Nørvang var. *minuta* Nørvang
- Elphidiella arctica* (Parker and Jones)
- Miliammina groenlandica* Cushman

The fauna in the southern Gulf of Maine differs by

containing numerous species which are also abundant south of Cape Cod.

Sediments from several of the areas covered in this report can be distinguished as to area of origin by distinctive faunal characteristics, such as relative frequencies, restricted distribution of certain species, relative population size, and relative abundance of species. The local faunal differences are relatively minor features superimposed on a general faunal similarity which is characteristic of the region as a whole. Baffin Bay is the one area which does not have any apparent faunal distinction. This may be the result of a large body of water having unlimited communication with several adjacent water areas. Under such conditions faunal mixing may prevent the development of a distinctive assemblage. Additional samples from Baffin Bay, on the other hand, may reveal features which can differentiate it from adjacent areas.

The Thule samples are distinctive in the high percentage of *Eggerella advena* (Cushman) and in the relatively low percentage of *Haplophragmoides glomeratum* (Brady).

The single Kane Basin sample has an unusually high population, an unusually high percentage of *Cibicides lobatulus* (Walker and Jacob), relatively high frequency of *Elphidiella arctica* (Parker and Jones), and also contains *Oolina costata* (Williamson). The Kennedy Channel sample apparently has no distinctive elements.

Lancaster Sound samples have the most persistent occurrences of *Ammodiscus gullmarensis* Höglund. *Trochammina quadriloba* Höglund is essentially restricted to this area, and most of the records of *Virgulina* sp. cf. *V. complanata* Egger are from here. *Nonion barleeianum* (Williamson) is essentially restricted to Baffin Bay and vicinity and Lancaster Sound.

Four of the five samples from Dundas Harbor are characterized by relatively high populations, by the presence of *Ammobaculites cassis* (Parker) and *Discorbis* sp. at most stations, high frequencies of *Elphidium incertum* (Williamson) and vars. at all stations, absence of or very low frequency of *Haplophragmoides glomeratum* (Brady), *Proteonina atlantica* Cushman, *Textularia earlandi* Parker (Ms.), *Textularia torquata* Parker (Ms.), and *Trochammina nana* (Brady), and high frequency of *Virgulina fusiformis* (Williamson).

The Toy Bay Samples have very low populations (20 or less/sample) and a small number of species. The fauna is almost exclusively composed of *Miliammina groenlandica* Cushman, *Spiroplectammina bifurcata* (Parker and Jones), and *Textularia torquata*, Parker (Ms.).

The Burnett Creek sample has a large population with several species dominated by *Elphidium incertum* (Williamson) and vars., *Cassidulina islandica* Höglund var. *minuta* Höglund, and *Cassidulina norcrossi* Cushman.

The fauna in Wellington Channel is distinct in the



high frequencies of *Cassidulina norcrossi* Cushman, presence of *Elphidiella arctica* (Parker and Jones) at most stations, low frequencies of *Haplophragmoides glomeratum* (Brady), relative abundance of *Nonion labradoricum* (Dawson), presence of *Oolina costata* (Williamson) at most stations, low frequency of *Protonina atlantica* Cushman and *Trochammina nana* (Brady), and relative abundance of *Virgulina fusiformis* (Williamson).

Melville Sound is characterized by the following species which are completely or essentially restricted to that area:

*Psammospaera fusca* F. E. Schultze

*Reophax nodulosa* Brady

*Reophax* sp. cf. *R. scorpiurus* Montfort

*Trochammina inflata* (Montagu)

*Trochammina atlantica* Parker

*Labrospira crassimargo* (Norman) reaches its highest frequency here.

#### REFERENCES

- PHLEGER, F. B., 1951, Ecology of Foraminifera, Northwest Gulf of Mexico, Pt. 1, Foraminifera Distribution, Geol. Soc. Amer., Mem. 46, p. 3-5.  
Contributions from the Scripps Institution of Oceanography, New Series, No. 574.  
Contribution No. 9 from the Marine Foraminifera Laboratory.

#### LOCATION OF STATIONS

##### Orange Peel Samples

No.	Depth-meters	Latitude	Longitude
OP 2	188	72°48'N	58°30'W
OP 3	244	71°42'N	57°51'W
OP 4	230	73°37'N	59°32'W
OP 5	256	74°38'N	62°47'W
OP 6	621	74°10'N	60°54'W
OP 7	877	73°49'N	59°06'W

OP 8	823	74°16'N	59°05'W
OP 9	38	74°35'N	82°11'W
OP 10	31	74°35'N	82°11'W
OP 11	592	74°32'N	79°50'W
OP 12	629	74°46'N	74°25'W
OP 13	391	74°38'N	78°28'W
OP 14	40	74°35'N	82°11'W
OP 15	31	76°38'N	68°48'W
OP 16	31	76°38'N	68°48'W
OP 17	31	76°38'N	68°48'W
OP 18	658	74°18'N	82°30'W
OP 19		74°25'N	86°45'W
OP 20	276	74°26'N	89°07'W
OP 21	31	76°38'N	68°48'W
OP 22	439	73°57'N	87°05'W
OP 24		73°37'N	80°42'W
OP 26	345	80°18'N	67°42'W
OP 27	124	74°34'N	110°40'W
OP 28	124	74°34'N	110°40'W
OP 29	124	74°34'N	110°40'W
OP 30	137	75°22'N	93°22'W
OP 31	137	75°22'N	93°22'W

#### CORE SAMPLES

No.	Depth-meters	Latitude	Longitude
C 1	38	74°35'N	82°11'W
C 2	38	74°35'N	82°11'W
C 3	31	76°38'N	68°48'W
C 4	31	76°38'N	68°48'W
C 5	457	74°03'N	87°05'W
C 6	439	74°08'N	87°05'W
C 7	419	74°13'N	87°05'W
C 8	448	74°18'N	87°05'W
C 9		73°37'N	80°42'W
C 10		73°37'N	80°42'W
C 11		73°37'N	80°42'W
C 12		73°37'N	80°42'W
C 13	124	78°53'N	73°35'W
C 14	124	74°34'N	110°40'W
C 15	124	74°34'N	110°40'W
C 16	124	74°34'N	110°40'W
C 17	409	74°15'N	112°35'W
C 18	155	75°22'N	93°22'W
C 19	155	75°22'N	93°22'W
C 20	126	75°55'N	93°14'W

## 62. FORAMINIFERA FROM CRETACEOUS-TERTIARY-TRANSITIONAL STRATA OF THE HODNA MOUNTAINS, ALGERIA\*

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(Utrecht, Holland)

ABSTRACT—From Cretaceous-Tertiary transitional marly beds, considered to be entirely or for the larger part approximately Danian age, 43 species and varieties of Foraminifera are described, of which 9 species and two varieties are new. A short discussion of the age of the strata and of the ecology of the foraminiferal associations is given.

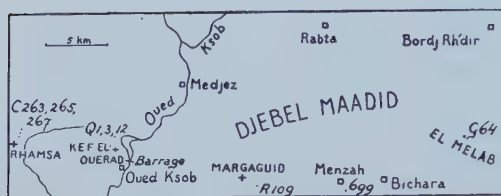
#### INTRODUCTION

During a mapping survey in the mountainous country along part of the northern border of the Hodna Basin, Algeria (1947-1949), several samples were taken at random from marls out of a complex of alternating

marls and limestones of about 80 meters thickness. These samples proved to contain many Foraminifera. The sequence of marls and limestones is stratigraphically of intermediate position between beds, which can be assigned with certainty to the Maestrichtian below and the Eocene above. The localities, from where the samples have been taken, are mainly scattered along a narrow strip of some 40 km. length. They have been plotted on the accompanying sketch-map (Text fig. 1).

The stratigraphy of the Cretaceous-Tertiary transitional beds of this region has been well-studied,

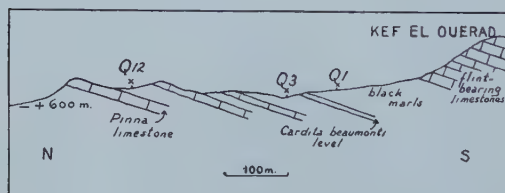
\* Contribution of the Paleontological Department of the State University of Utrecht.



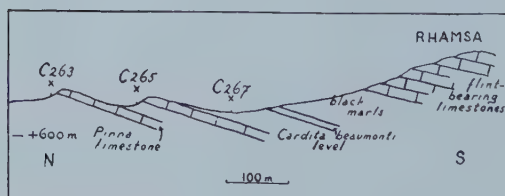
Text Fig. 1: Sample Localities, Hodna Basin, Algeria

especially by SAVORNIN (lit. 3) and FLANDRIN (lit. 2). During the geological mapping it was found, however, that a study of the detailed stratigraphy of these layers is severely hampered by the occurrence of lateral facies changes. In the region along and to the west of Oued Ksob two fairly constant levels could be mapped, which fortunately, are situated respectively near the base and close to the top of this complex. In the lower part of the sequence a thick, light-coloured limestone occurs, in which, in addition to other ill-preserved fossils, numerous fragments of *Pinna* sp. were observed. In the upper portion of the 80 meters' complex a thin, fossiliferous, yellowish, marly zone with numerous *Cardita beaumonti* d'Archiac was encountered, lying at the base of a series of dark gypsiferous clays, which in turn are overlain by the topographically protruding complex of Eocene (Ypresian) limestones with silex.

In two sections on the northern slopes of Rhamsa and of Kef el Ouerad, three samples of each of the sections contained smaller Foraminifera and a few larger ones. Their exact stratigraphic position has been marked on the accompanying drawings (Text figs. 2 and 3). Sample 699 has been taken from a level, slightly above that of *Cardita beaumonti*, in the



Text Fig. 2: Stratigraphic Section: Localities Q1, Q3, and Q12 Dano-Montian, Kef el Ouerad, Algeria



Text Fig. 3: Stratigraphic Section: Localities C263, C265, and C267 Dano-Montian, Rhamsa, Algeria

southern Djebel Maadid near Oued Menzah. Sample G 64 is a composite one, derived from beds directly below, in and slightly above this same horizon, in the isolated outcrop of these strata of El Melab, south of Bordj Rh'dir. The exact stratigraphical position of sample R 109 is unknown.

The megafauna of the higher part of the sequence involved, in and some distance below the level, marked by the abundance of *Cardita beaumonti*, is characterized by *Cardita beaumonti* d'Archiac, *Roudaireia drui* Munier-Chalmas and *Exogyra overwegi* von Buch. Moreover, especially near the Rhamsa, numerous, mainly fragmentary oysters, were encountered in several horizons throughout the section, even some meters below the *Pinna*-limestone. These strongly variable oysters may all be considered to belong to a single species, most likely *Alectryonia aucapitaini* (Coquand).

The three first mentioned species of these mollusks in the higher part of the Cretaceous-Tertiary transitional strata are now generally considered to characterize the North African Danian. *Alectryonia aucapitaini* is considered by SAVORNIN to be restricted to the Danian in the vicinity of Oued Ksob. It should be remarked, however, that the age of the layers, dealt with here, is evaluated differently by SAVORNIN and FLANDRIN. As far as can be concluded from his general description, SAVORNIN places the complex between the *Pinna*-limestone and the *Cardita beaumonti*-level nearly entirely in the Danian; the latter horizon, however, he considers to be Montian. On the other hand, FLANDRIN places the majority of our section in the Uppermost Maestrichtian, whereas he considers the Danian to range from about 25 meters below to 35 meters above the *Cardita beaumonti*-horizon. The upper limit of FLANDRIN's Danian is evidently based on the occurrence of some oyster-beds, which contain a. o. *Alectryonia villei* (Coquand), near the top of the dark gypsiferous clays. This *A. villei* is generally considered to be a typical Cretaceous species, occurring abundantly in the Campanian and the Maestrichtian of this part of North Africa. Unfortunately, the oysters, collected during our mapping survey, are too poorly preserved to allow a specific determination, but some fragments from these oyster-beds were observed, which, indeed, strongly resemble the well-known Cretaceous species.

The stratigraphical problems concerning our strata, are not yet satisfactorily solved. It is therefore thought recommendable at present either to name these beds simply "Cretaceous-Tertiary transitional strata" or possibly to use the name Dano-Montian, introduced by FLANDRIN (lit. 2) and SIGAL (lit. 4). The writer is inclined to place the larger part of or even the entire section in the Danian, as in none of his samples a typical Maestrichtian microfauna was encountered. On the other hand, however, no criterions are available to separate the Danian from the Paleocene.



The microfaunal assemblages of the samples have a rather different aspect with respect to associations, known from other localities of the Algerian Cretaceous-Tertiary transitional sediments (lit. 1 and 4). The latter have a more cosmopolitan character and compare better with several described fauna of America, as for instance the Midway of Texas, and also with those from the Caucasus and Sweden. This difference in faunal composition may be explained by assuming that the corresponding sediments along the northern border of the Hodna Basin were deposited under rather extreme, i. e. comparatively shallow, and possibly partly brackish water conditions. The lateral facies changes of the individual layers, the numerous oyster-beds and the gypsum content of many of the samples support this opinion. Further evidence is found in several of the species which were reported as shallow water forms elsewhere or which may be anticipated as such. The occurrence of many of the species with numerous individuals of relatively small, but constant, size in samples with a rather low number of species, together with the comparatively high amount of new species, may also point to the former existence of some special environmental influence during sedimentation.

The established stratigraphical ranges of earlier described species in our samples indicate a dominance of Danian-Paleocene forms. Only three of the determined species have so far been recorded from Upper

Senonian strata only: *Loxostomum plaitum*, *Siphogenerinoides parva* and *Omphalocyclus macropora*. Especially the latter is an important species of the European Uppermost Cretaceous (excluding Danian), for instance of the Maestrichtian at its type-locality Maestricht. REY (in FLANDRIN, lit. 2, p. 155), however, reports this species from the Algerian Danian. Only three species are probably restricted, as far as known, to the Eocene: *Nonion acutidorsatus*, *Gümbelitra triserialis* and *Globorotalia wilcoxensis* var. *acuta*. The majority of the other earlier described 25 species are known from, and in many cases restricted to, Danian, Paleocene or Danian-Paleocene. Comparing the foraminiferal associations from the Hodna region with those of about the same age in the neighbourhood of Constantine (lit. 1 and 4), a somewhat better correlation is indicated with the fauna of the Velasco shale and Tabasco formations of Mexico and with the Lizard Springs marls of Trinidad. Relations exist also with the fauna of the Paleocene of El-Guss-Abu-Said, Egypt, and of the Netherlands. It has been pointed out already that distinct Maestrichtian markers are absent in our material, but the conclusion herefrom is weakened by the scarcity of pelagic species, though those that are present, point to levels, younger than Upper Senonian.

When combining our individual samples to a tentative single stratigraphical sequence, no distinct zoning is observed from the vertical distribution of the spe-

	C 263	Q 12	C 265	C 267	Q 3	G 64	699	Q 1
<i>Haplophragmoides eggeri</i> Cushman	×						×	
<i>Trochammina bradyi</i> (Schwager)		×			×		×	×
<i>Nodosaria bacillum</i> Defrance					×		×	
<i>Vaginulina legumen</i> (Linné)					×	×		
<i>Nonion acutidorsatus</i> Dam	×	×	×			×	×	
<i>Nonionella insecta</i> (Schwager)	×	×						
<i>Gümbelina morsei</i> Kline	×					×	×	
<i>Bulimina trigonalis</i> Dam	×				×			
<i>Virgulina troosteri</i> Drooger n. sp.	×	×					×	×
<i>Valvulineria koenigswaldi</i> Drooger n. sp.	×					×	×	×
<i>Valvulineria palmi</i> Drooger n. sp.	aff.	×						
<i>Rotalia sigali</i> Drooger n. sp.			×	×				
<i>Globigerina voluta</i> White	×	×	×		×	×		
<i>Cibicides praecursorius</i> (Schwager) and vars.	×	×	×	×				
<i>Anomalina midwayensis</i> (Plummer) and vars.					×	×		
<i>Anomalina newmanae</i> ksobensis Drooger n. var.						×	×	×
<i>Virgulina cruysi</i> Drooger and new var.						×	×	

Table 1: Distribution Chart of some of the Dano-Montian Hodna Mountains Beds in Algeria with tentative stratigraphic sequence of localities indicated on Text figs. 1, 2, and 3.

cies. This negative result is probably mainly due to a lack of sufficient data. Possibly the middle of the "section" (C 265 and C 267) represents an intercalation of sediments, deposited under extremely aberrant environmental conditions. Although this may have been of local importance only, it may explain the interrupted occurrences of some, otherwise common species, as for instance *Virgulina troosteri* and *Valvulineria koenigswaldi*.

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## DESCRIPTION OF THE SPECIES

### Family AMMODISCIDAE

Genus *Ammodiscoides* Cushman, 1909

*Ammodiscoides turbinatus* Cushman

*Ammodiscoides turbinatus* CUSHMAN, 1909, Proc. U. S. Nat. Museum, vol. 36, no. 1676, p. 423, pl. 33, f. 1-6; CUSHMAN and STAINFORTH, 1946, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 15, pl. 1, f. 28, 29.

As far as known this species evidently has a long stratigraphical range: Upper Cretaceous to Recent.

*Occurrence*—Rare in C 263.

### Family LITUOLIDAE

Genus *Haplophragmoides* Cushman, 1910

*Haplophragmoides eggeri* Cushman

Plate 15, figure 1

*Haplophragmoides eggeri* CUSHMAN, 1926, Bull. Am. Ass. Petr. Geol., vol. 10, p. 583, pl. 15, f. 1; CUSHMAN and JARVIS, 1932, Proc. U. S. Nat. Museum, Bull. 80, art. 14, p. 12, pl. 3, f. 2; GALLOWAY and MORREY, 1932, Journ. of Pal., vol. 5, p. 333, pl. 37, f. 6; GLAESSNER, 1937, Probl. Paleont., Moscow Univ., vols. 2-3, p. 361, pl. 1, f. 10.

*Remarks*—Many of the Algerian specimens, considered to belong to this species, have been somewhat distorted, resulting in rather varying external appearances of the test, because of different directions of distortion for the separate specimens. In some individuals the sutures appear strongly limbate (see Pl. 15, fig. 1).

*Occurrence*—Few in 699 and R 109, rare in C 263.

Originally described from the Velasco shale of Mexico. Reported from Uppermost Cretaceous (about Danian) deposits in Mexico and Trinidad and from the Paleocene of the Caucasus.

### Family TEXTULARIIDAE

Genus *Spiroplectammina* Cushman, 1927

*Spiroplectammina raveni* Drooger, n. sp.

Plate 15, figures 2a-3b

*Description*—Test minute, about  $1\frac{1}{2}$  times as long as broad, gradually tapering to the broadly rounded initial end, compressed, early portion distinctly coiled, later part biserial with inter-fingering chambers; periphery sharp, slightly keeled and often indented; chambers distinct, in the biserial portion about twice as broad as high; sutures strongly limbate, occasionally raised in the early portion, in the adult usually slightly depressed and somewhat curved, forming an angle with the median line of about 70 degrees in their inner portion; wall arenaceous, rather roughly finished; aperture a narrow slit at the base of the final chamber. Maximum observed length 0.25 mm.

*Remarks*—Except for its much smaller size *S. raveni* differs from *S. richardi*: Martin (1943, Publ. Stanford Univ., Univ. Ser., Geol. Sci., vol. 3, no. 3, p. 104, pl. 5, f. 3) from the Eocene-Paleocene Lodo formation of California by its strongly limbate sutures, which show a different arrangement near the median line, whereas the early coiled stage is relatively better developed in the Algerian species.

*Occurrence*—Rare in Q 1.

Genus *Textularia* DeFrance, 1824

*Textularia plummerae* Lalicker

Plate 15, figures 4a-5

*Textularia cocaena* PLUMMER (non Gümbel), 1926, Univ. Texas Bull. 2644, p. 67, pl. 3, f. 2.

*Textularia plummerae* LALICKER, 1935, Contrib. Cushman Lab. Foram. Res., vol. 11, p. 50, pl. 6, f. 10; GLAESSNER, 1937, Probl. Paleont., Moscow Univ., vols. 2-3, p. 364.

*Remarks*—Typical specimens are rare in our material, but many others were found with obviously the same features, but in which the test is strongly compressed, probably due to collapse of the chamber walls (see Pl. 15, fig. 5). In these specimens the sutures appear as somewhat limbate and often slightly elevated ridges.

The Algerian specimens differ from *T. plummerae* in being of much smaller size (maximum length 0.35 mm.). Megalospheric specimens resemble best those pictured by Lalicker; microspheric ones are closest to the specimen pictured by Plummer.

*Occurrence*—Few in Q 1.

*T. plummerae* has been reported from the Upper Midway of Texas and the Paleocene of the Caucasus.

### Family VERNEUILINIDAE

Genus *Gaudryina* Orbigny, 1839

*Gaudryina laevigata* Franke var. *pyramidata* Cushman

Plate 15, figure 6

*Gaudryina laevigata* Franke var. *pyramidata* CUSH-



MAN, 1926, Bull. Am. Ass. Petr. Geol., vol. 10, p. 587, pl. 16, f. 8; CUSHMAN and JARVIS, 1928, Contrib. Cushman Lab. Foram. Res., vol. 4, p. 92, pl. 13, f. 6; WHITE, 1928, Journ. of Pal., vol. 2, p. 313, pl. 42, f. 7; REY, 1948, in Flandrin, Contribution à l'Etude stratigraphique du Nummulitique Algérien, p. 155.

*Gaudryina pyramidata* Cushman, CUSHMAN and RENZ, 1946, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 21, pl. 2, f. 21; CUSHMAN and RENZ, 1948, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 13, pl. 3, f. 4.

*Occurrence*—Common in Q 3.

Originally described from the Velasco shale of Mexico. Furthermore recorded from the Upper Cretaceous—lower zone of the Lizard Springs formation—and the Eocene of Trinidad and from the Danian of Algeria.

### Family TROCHAMMINIDAE

Genus *Trochammina* Parker and Jones, 1859

*Trochammina bradyi* (Schwager)

Plate 15, figures 7a-c

*Haplophragmium bradyi* SCHWAGER, 1883, Palaeontogr., vol. 30, pt. 1, pal. pt., p. 117, pl. 29, f. 19.

*Haplophragmoides diagonis* CARSEY, 1926, Univ. Texas Bull. 2612, p. 22, pl. 3, f. 1.

*Trochammina diagonis* (Carsey) CUSHMAN, 1927, Contrib. Cushman Lab. Foram. Res., vol. 2, p. 84, pl. 10, f. 7; GALLOWAY and MORREY, 1931, Journ. of Pal., vol. 5, p. 332, pl. 37, f. 4.

*Haplophragmoides* sp.? WHITE, 1928, Journ. of Pal., vol. 2, p. 307, pl. 41, f. 4.

*Description*—Test slightly, often indistinctly, trochoid, strongly compressed, usually flattened by later distortion; periphery narrowly rounded, usually sharp, lobulate; chambers about six in the final whorl; sutures straight to moderately and often irregularly curved; wall finely arenaceous, generally smoothly finished; aperture indistinct. Maximum diameter 0.4 mm.

*Remarks*—It is highly probable that in all the above quoted references one and the same species is meant, the individuals of which are usually completely flattened by compression of the embedding sediment (see Pl. 15, fig. 7). As a result of this action the early characteristics of the test have mostly been obliterated, often giving a bilaterally symmetrical appearance to the test.

*Occurrence*—Common in Q 1, Q 3 and 699, few in Q 12.

The species was originally described from the Paleocene of El-Guss-Abu-Said, Egypt. It also occurs in beds of Taylor and Navarro age in Texas and in the Uppermost Cretaceous (about Danian) of Mexico.

### Family LAGENIDAE

Genus *Lenticulina* Lamarck, 1804

*Lenticulina* sp. cf. *L. velascoensis* (White)

*Astacolus velascoensis* WHITE, 1928, Journ. of Pal., vol. 2, p. 202, pl. 28, f. 12.

*Remarks*—The few specimens, found in the Algerian material, are rather badly preserved. In most of them the sutures are moderately raised and for which reasons they are tentatively referred to White's species.

*Occurrence*—Rare in Q 3.

Reported from Upper San Felipe to Velasco of Mexico.

Genus *Dentalina* d'Orbigny, 1826

*Dentalina* sp. cf. *O. inornata* Orbigny

*Dentalina inornata* ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 44, pl. 1, f. 50, 51.

*Dentalina* aff. *inornata* Orbigny, SCHWAGER, 1883, Palaeontogr., vol. 30, pt. 1, pal. pt., p. 107, pl. 26, f. 3.

*Remarks*—Few fragmentary specimens were found, which resemble the one pictured by Schwager from the Paleocene of Egypt.

*Occurrence*—Rare in C 265.

Genus *Nodosaria* Lamarck, 1812

*Nodosaria bacillum* DeFrance

Plate 15, figure 8

*Nodosaria bacillum* DEFANCE, 1826, Dict. des Sc. Nat., vol. 35, p. 127, pl. 13, f. 4; D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 40, pl. 1, f. 40-47.

*Remarks*—Many fragments of a large costate *Nodosaria* were found, usually consisting of single chambers only, showing the following characteristics: chambers globular to somewhat longer than broad, variably ornamented with 8-25 heavy, longitudinal costae, which pass in diminishing strength, but uninterrupted, over the broad, deeply depressed sutures. Maximum observed breadth of a single chamber 0.8 mm.

In the literature numerous specific names were given to similar forms of *Nodosaria*, occurring in sediments from many parts of the world and from widely varying stratigraphic levels. Several of these forms have been referred to *N. affinis* Orbigny, which in our opinion is identical with DeFrance's species. Thus the Algerian fragments are considered to belong to the earlier described *N. bacillum*.

*Occurrence*—Rare in Q 3, 699 and R 109.

In addition to the rare occurrences in some of the samples from the southern slopes of the Djebel Maadid, this species is abundant in several samples from the Cretaceous-Tertiary transitional strata of the neighbourhood of Ain Fakroun and Oued Athmenia (Dept. of Constantine).

Genus *Vaginulina* Orbigny, 1826

*Vaginulina legumen* (Linné)

Plate 15, figures 9, 10

*Nautilus legumen* LINNÉ, 1758, Syst. Nat., ed. 10, vol. 1, p. 711, (Plancus, pl. 1, f. 7g-i).

*Occurrence*—Common in Q 3, few in G 64, rare in E 29D (collection Cruys). It is the only species present in E 29D from the Cretaceous-Tertiary transitional marls in the vicinity of Bordj Rh'dir.

Originally described as a recent species from the Adriatic sea, *V. legumen* has subsequently been widely reported from numerous different stratigraphical levels from Mesozoic to Recent. Many of these references, however, do not seem to belong to this species.

Family NONIONIDAE

Genus *Nonion* Montfort, 1808

*Nonion acutidorsatum* Dam

Plate 15, figures 11a, b

*Nonion acutidorsatum* DAM, 1944, Meded. Geol. Stichting, Ser. C, vol. 5, no. 3, p. 108, pl. 3, f. 19.

*Remarks*—Part of our specimens closely resemble the one, pictured by ten Dam, whereas others are somewhat more rounded in outline or with a slightly thicker test (see Pl. 15, fig. 11). The average number of chambers in the final whorl is eight, thus slightly less than in the typical form. Some specimens approach the type of the recent *N. labradoricum* (Dawson) (1860, Canad. Naturalist, vol. 5, p. 191, f. 4), whereas others again are slightly oblique and *Nonionella*-like. Notwithstanding these minor differences it is considered preferable to place the group of Algerian specimens as a whole in *N. acutidorsatum*.

*Occurrence*—Common in Q 12 and C 265, few in C 263, 699 and G 64.

Originally described from the Eocene (Lutetian) of the Netherlands.

*Nonion sublaeve* Dam

Plate 15, figure 12

*Nonion sublaeve* DAM, 1944, Meded. Geol. Stichting, ser. C, vol. 5, no. 3, p. 109, pl. 3, f. 8.

*Occurrence*—Few in C 265.

Originally described from the brackish-water Paleocene of the Netherlands.

Genus *Nonionella* Cushman, 1926

*Nonionella insecta* (Schwager)

Plate 15, figures 13a-c

*Anomalina insecta* SCHWAGER, 1883, Palaeontogr., vol. 30, pt. 1, pal. pt., p. 128, pl. 28, f. 2a-d.

*Nonionella insecta* (Schwager) CUSHMAN and PONTON, 1932, Contrib. Cushman Lab. Foram. Res., vol. 8, p. 65, pl. 8, f. 13, 14; GLAESSNER, 1937, Probl. Palaeont., Moscow Univ., vols. 2-3, p. 368.

*Remarks*—The Algerian representatives of this spe-

cies are small (larger diameter about 0.2 mm.) and closest to the young stage of the species, pictured by Cushman and Ponton. They show a faint resemblance with some of the individuals of *Nonion acutidorsatum* Dam, occurring in the same samples, but it was impossible to find convincing transient specimens between them and immature individuals of *Nonion acutidorsatum*. For this reason they are treated as belonging to a separate species.

*Occurrence*—Few in Q 12 and C 263.

Originally described from the Paleocene of El-Guss-Abu-Said, Egypt. Reported furthermore from the Wilcox Eocene of Alabama and the Paleocene of the Caucasus.

*Nonionella ovata* Brotzen

*Nonionella ovata* BROTZEN, 1948, Sver. Geol. Unders., Avh., ser. C, no. 493, årsb. 42, no. 2, p. 68, pl. 10, f. 13, 14.

*Remarks*—In sample Q 1, slightly above the *Cardita beaumonti*-level near the river Ksob, a single specimen of *Nonionella* was found, which is considered to belong to Brotzen's species. The only differing feature is in the very slight depression of the sutures in the Algerian specimen. Because of this characteristic there is some resemblance with the Upper Cretaceous *N. austriana* Cushman (1933, Contrib. Cushman Lab. Foram. Res., vol. 9, p. 57, pl. 7, f. 2), which is, however, considerably more compressed.

*Occurrence*—Rare in Q 1.

Described from the Paleocene of Sweden.

Family HETEROHELICIDAE

Genus *Gümbelina* Egger, 1899

*Gümbelina morsei* Kline

Plate 15, figure 14

*Gümbelina morsei* KLINE, 1943, Bull. Miss. Geol. Survey, no. 53, p. 44, pl. 7, f. 12.

*Remarks*—An insignificant number of small and strongly variable *Gümbelina* specimens from some of the samples seems to be closest to this species. Since variation among them is rather wide, several of the specimens approach the types of other species, but specific determination of these more or less aberrant forms would be impossible because of the lack of sufficient material. As a matter of fact, in the genus *Gümbelina* several of the described species are less different from one another than the specimens of a single fossil assemblage, which are reasonably considered to belong to one and the same species. When the variation of the individuals in a newly established species is insufficiently described as is often the case, later specific determination is severely hampered. Among the material of our samples some larger specimens are close to *G. striata* (Ehrenberg) and *G. ultimatumida* White, others again approach the type of *G. midwayensis* Cushman.



*Occurrence*—Few in C 263, 699 and G 64.

Originally described from the Paleocene Midway series of Mississippi.

Genus *Gümbelitra* Cushman, 1933

*Gümbelitra triseriata* (Terquem)

Plate 15, figures 15, 16

*Textilaria triseriata* TERQUEM, 1882, Mém. Soc. Géol.

France, sér. 3, tome 2, p. 145, pl. 15, f. 10.

(?) *Gümbelitra stavensis* BANDY, 1949, Bull. Am.

Paleont., vol. 32, no. 131, p. 124, pl. 24, f. 5.

*Remarks*—Many of the Algerian specimens are somewhat twisted or irregular in the later stages of individual development. The aperture is a semicircular opening at the base of the final chamber. Measured length up to 0.20 mm.

It should be remarked that in our material *G. triseriata* is found together with numerous representatives of *Bulimina trigonalis* Dam. In general appearance both species are very similar, the main distinguishing feature being the shape of the aperture. Unfortunately, in many specimens the aperture is rather ill-preserved, thus causing doubtful determinations in such cases. Intergradation of both species could not be observed, but it should be borne in mind that the indistinct apertural characteristics in many individuals hamper a clear decision on this subject. Such an intergradation is thought to be not entirely impossible, as many older species of *Bulimina* show a considerable amount of variation in the shape of their aperture.

*Occurrence*—Few in C 263.

Originally described from the Lower Eocene of France. Specimens resembling *G. stavensis* Bandy from the Claiborne Eocene of Alabama are equally represented in the Algerian material. They cannot be separated specifically here.

#### Family BULIMINIDAE

Genus *Buliminella* Cushman, 1911

*Buliminella parvula* Brotzen

*Buliminella parvula* BROTZEN, 1948, Sver. Geol. Unders., Avh., ser. C, no. 493, årsr. 42, no. 2, p. 57, pl. 10, f. 3, 4.

*Remarks*—In sample Q 3 one specimen was found, which closely resembles the one pictured by Brotzen as Fig. 3 from the Paleocene of Sweden.

Genus *Bulimina* d'Orbigny, 1826

*Bulimina marksi* Drooger, n. sp.

Plate 15, figures 17a-19

*Description*—Test small,  $1\frac{1}{2}$  times to twice as long as broad, bluntly triangular in transverse section, sides about parallel, initial end truncate and somewhat rounded; early chambers indistinct, later ones triserial, slightly inflated and overlapping, very slowly increasing in size as added; sutures somewhat depressed and sinuous; wall smooth, distinctly and rather coarsely

perforate; aperture slightly elongate, at the inner margin of the last-formed chamber, extending upwards into the apertural face, lying in a wide depression of the latter. Length up to 0.20 mm.

*Remarks*—The most characteristic features of *B. marksi*, which also serve to distinguish it from the other representatives of the genus *Bulimina*, are the truncate initial end and the triangular, prismatic appearance of the test. Possibly *B. rugifera* Glaessner (1937, Probl. Paleont., Moscow Univ., vols. 2-3, p. 372, pl. 2, f. 19) from the Upper Senonian and the Paleocene of the Caucasus and the same species, reported from the Upper Velasco of Mexico [*B. velascoensis* White (non Cushman), 1929, Journ. of Pal., vol. 3, p. 50, pl. 5, f. 13] are related to the Algerian species, which is different by the more truncate lower part of the test and the lack of surface ornamentation. Another possibly allied species is *B. mendezensis* White (1929, Journ. of Pal., vol. 3, p. 49, pl. 5, f. 10) from the Upper Cretaceous Mendez shale of Mexico, which differs from *B. marksi* by the less truncate initial end and the more rounded cross section.

*Occurrence*—Common in C 263.

#### *Bulimina ovata* Orbigny

*Bulimina ovata* ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 185, pl. 11, f. 13, 14; CUSHMAN and PARKER, 1937, Contrib. Cushman Lab. Foram. Res., vol. 13, p. 47, pl. 6, f. 4, 5; GLAESSNER, 1937, Probl. Paleont., Moscow Univ., vols. 2-3, p. 371; DAM, 1944, Meded. Geol. Stichting, ser. C, vol. 5, no. 3, p. 111, pl. 3, f. 10, 11; MARKS, 1951, Contrib. Cushman Found. Foram. Res., vol. 2, pt. 2, p. 57.

*Occurrence*—Rare in Q 3.

Originally described from the Miocene of the Vienna Basin. Probably ranging from Upper Cretaceous to Recent.

#### *Bulimina trigonalis* Dam

Plate 15, figures 20-22

*Bulimina trigonalis* DAM, 1944, Meded. Geol. Stichting, ser. C, vol. 5, no. 3, p. 112, pl. 3, f. 16, 17.

*Remarks*—Especially the smaller Algerian specimens closely resemble the individuals, pictured by ten Dam. In most of the larger ones the later chambers are somewhat more rapidly increasing in size than those of the early stages of individual development. Moreover the final chambers become more strongly twisted than those of the pictured Dutch forms, often tending towards biseriality. Length up to 0.4 mm.

*Occurrence*—Common to abundant in Q 3 and C 263.

Originally described from the littoral-marine Paleocene of the Netherlands.

Genus *Virgulina* Orbigny, 1826

*Virgulina troosteri* Drooger, n. sp.

Plate 15, figures 23a-24

*Description*—Test small, elongate,  $2\frac{1}{2}$ -4 times as

long as broad, slightly to moderately compressed, sides about parallel to slowly tapering to the initial end; early triserial portion relatively very small, biserial part somewhat twisted, made up of 6-12 slightly inflated chambers; early biserial chambers broader than high, increasing upwards in relative height, resulting in final chambers with greater height than breadth; sutures distinct, slightly curved, making an angle of 50-80 degrees with the longer axis of the test, slightly depressed; wall smooth, finely perforate; aperture a large, wide opening at the inner margin of the final chamber. Length 0.24-0.36 mm., breadth about 0.9 mm.

*Remarks*—In general appearance *V. troosteri* resembles *V. tegulata* Reuss (1845, Verst. böhm. Kreide, pt. 1, p. 40, pl. 13, f. 81), reported from the Turonian of Central Europe and the same species pictured by Cushman (1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 4, pl. 1, f. 9-12) from the Upper Cretaceous of North America, mainly differing in the shape of the aperture.

The species has been named in honor of the late S. G. Trooster, Professor of Geology of the State University of Utrecht.

*Occurrence*—Common in C 263 and 699, few in Q 1 and Q 12. Holotype and paratypes from C 263.

### *Virgulina cruyssi* Drooger, n. sp.

Plate 15, figures 25a-26b

*Description*—Test elongate,  $1\frac{1}{2}$ -3 times as long as broad, slightly compressed, occasionally from a somewhat oblique direction, more or less tapering, often with about parallel sides in the adult; triserial portion relatively small, biserial part slightly if at all twisted with 6-10 inflated chambers, which are in most larger specimens more or less protruding basally, forming processes, especially near the angles of the test; sutures depressed, at about right angles to the median line of the test; wall smooth, finely perforate; aperture large and wide, often with lateral extensions into the apertural face, at the inner margin of the last-formed chamber. Length up to 0.5 mm.

*Remarks*—The abundant specimens of *V. cruyssi* show a wide variation as to the general appearance of the test, the degree of overhanging of the chambers and the shape of the aperture. Those with a distinctly tapering test throughout may be microspheric individuals, whereas others, which are more abundantly present, with about parallel sides and a very small triserial initial part may represent the megalospheric generation. On account of the peculiar apertural features several specimens were tested with hydrochloric acid, after which action only trifling amounts of fer-

## EXPLANATION OF PLATE 15

FIGS.		PAGE
1.	<i>Haplophragmoides eggeri</i> Cushman; Sample 699; 65 $\times$ .	92
2a-3b.	<i>Spiroplectammina raveni</i> Drooger n. sp.; Sample Q 1; 2 holotype, 3 paratype; 2a, 3a side views, 2b, 3b apertural views; 95 $\times$ .	92
4a-5.	<i>Textularia plummerae</i> Lalicker; Sample Q 1; 4a side view, 4b apertural view, 5 side view of a distorted specimen; 95 $\times$ .	92
6.	<i>Gaudryina laevigata</i> Franke var. <i>pyramidata</i> Cushman; Sample Q 3; 65 $\times$ .	92
7a-c.	<i>Trochammina bradyi</i> (Schwager), distorted specimen; Sample 699; 7a dorsal view, 7b ventral view; 7c side view; 65 $\times$ .	93
8.	<i>Nodosaria bacillum</i> DeFrance; Sample Q 3; 33 $\times$ .	93
9, 10.	<i>Vaginulina legumen</i> (Linné); Sample Q 3; 33 $\times$ .	94
11a, b.	<i>Nonion acutidorsatus</i> Dam; Sample Q 12; 11a side view, 11b apertural view; 65 $\times$ .	94
12.	<i>Nonion sublaeve</i> ten Dam; Sample C 265; 65 $\times$ .	94
13a-c.	<i>Nonionella insecta</i> (Schwager); Sample Q 12; 13a, b side views, 13c apertural view; 95 $\times$ .	94
14.	<i>Gümbelina morsei</i> Kline; Sample C 263; 95 $\times$ .	94
15, 16.	<i>Gümbeltria triseriata</i> (Terquem); Sample C 263; 95 $\times$ .	95
17a-19.	<i>Bulimina marksi</i> Drooger n. sp.; Sample C 263; 17 holotype, 18, 19 paratypes; 17a, b, 18, 19 side views, 17c apertural view; 95 $\times$ .	95
20-22.	<i>Bulimina trigonalis</i> Dam; Sample Q 3; 95 $\times$ .	95
23a-24.	<i>Virgulina troosteri</i> Drooger n. sp.; Sample C 263; 23 holotype, 24 paratype; 23a, 24 front views, 23b side view, 23c apertural view; 95 $\times$ .	95
25a-26b.	<i>Virgulina cruyssi</i> Drooger n. sp.; Sample G 64; 25 holotype, 26 paratype, obliquely compressed specimen; 25a, 26a front views, 25b, 26b side views, 25c apertural view; 65 $\times$ .	96
27a-28.	<i>Virgulina cruyssi</i> Drooger var. <i>maadidensis</i> Drooger n. var.; Sample 699; 27 holotype, 28 paratype; 27a 28 front views, 27b side view, 27c apertural view; 65 $\times$ .	97
29a-30.	<i>Bolivina betieri</i> Drooger n. sp.; Sample C 263; 29 holotype, 30 paratype; 29a, 30 side views, 29b apertural view; 95 $\times$ .	97
31.	<i>Siphogenerinoides parva</i> Cushman; Sample Q 3; 65 $\times$ .	98
32a-33c.	<i>Valvulineria koenigswaldi</i> Drooger n. sp.; Sample G 64; 32 holotype, 33 paratype; 32a, 33a dorsal views, 32b, 33b ventral views, 32c, 33c apertural views; 95 $\times$ .	98
34a-35c.	<i>Valvulineria palmi</i> Drooger n. sp.; Sample Q 12; 34 holotype, 35 paratype; 34a, 35a dorsal views, 34b, 35b ventral views, 34c, 35c apertural views; 95 $\times$ .	98
36a-37c.	<i>Rotalia sigali</i> Drooger n. sp.; Sample C 265; 36 holotype, 37 paratype; 36a, 37a dorsal views, 36b, 37b ventral views, 36c, 37c peripheral views; 65 $\times$ .	99





Drooger, Algerian Cretaceous—Tertiary Foraminifera



Drooger, Algerian Cretaceous—Tertiary Foraminifera



ruginous material remained undissolved, these probably originating from secondary impregnation, as was observed in many more species of these samples. Because of this negative result the species is thought to belong to the genus *Virgulina*.

*V. cruysi* differs from *V. primitiva* Cushman (1936, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 46, pl. 7, f. 1) and *V. subcretacea* Cushman (ibid., p. 46, pl. 7, f. 2) from the Lower Cretaceous of Texas and *V. miniacea* Cushman and Bermudez (1936, Contrib. Cushman Lab. Foram. Res., vol. 12, p. 30, pl. 5, f. 14) from the Upper Eocene of Cuba, by a relatively long, rather regularly biserial portion of the test and by the peculiar processes of the chambers. The latter characteristic together with the shape of the aperture distinguish *V. cruysi* from *V. sandegreni* Brotzen (1948, Sver. Geol. Unders., Avh., ser. C, no. 493, årsb. 42, no. 2, p. 65, pl. 9, f. 2) from the Lower Paleocene of Sweden.

*Occurrence*—Common in G 64.

***Virgulina cruysi* Drooger**  
var. *maadidensis* Drooger, n. var.  
Plate 15, figures 27a-28

*Description*—Variety differing from the typical by its smaller size, the relatively unimportant biserial stage and the aperture, which in larger specimens is strongly contracted at its base, often being entirely separated from the inner margin of the final chamber. Length up to 0.35 mm.

*Remarks*—The individuals of sample 699 are smaller and usually less developed than those of sample G 64, showing a predominance of the triserial part, which often makes up the entire test. In the largest specimens, which possess a biserial part of 2-4 chambers, the aperture is separated or nearly so from the inner margin of the last-formed chamber. The latter feature

allows to distinguish this variety from immature individuals of *V. cruysi*. Among the specimens of the latter in sample G 64 of El Melab no distinct representatives of *V. cruysi* var. *maadidensis* were encountered, whereas on the other hand in sample 699 mainly this variety is present. In another sample from the region of Bordj Rh'dir specimens were found which show a longer biserial portion of the test. Part of them somewhat resemble *Loxostomum cushmani* Wickenden (1932, Trans. Roy. Soc. Canada, ser. 3, vol. 26, sect. 6, p. 91, pl. 1, f. 6) from the American Upper Cretaceous.

*Occurrence*—Few in 699.

**Genus *Bolivina* Orbigny, 1839**

***Bolivina betieri* Drooger, n. sp.**

Plate 15, figures 29a-30

*Description*—Test minute,  $1\frac{1}{2}$ - $2\frac{1}{2}$  times as long as broad, gradually tapering to the rounded initial end, compressed, especially in the early portion of the test; periphery rounded; early chambers narrow, later ones more rapidly increasing in relative height and often also in thickness; sutures oblique, curved and slightly limbate in the early portion, in the upper part of the test crenulate with one or two deep reentrants on each side of the chambers, the crenulate sutures appearing rather abruptly; wall smooth, finely perforate; aperture elongately oval at the inner margin of the final chamber, extending to the top of the test. Length up to 0.25 mm.

*Remarks*—*B. betieri* differs from most other *Bolivina* species with crenulate sutures by the absence of these crenulations on the early chambers. Some variation exists as to the relative length of the test. Extremely short variants (see Pl. 15, fig. 30) show some resemblance with *B. plicatella* Cushman var. *mera* Cushman and Ponton (1932, Florida Geol. Survey, Bull. 9, p. 82,

EXPLANATION OF PLATE 16

FIGS.	PAGE
1a, b. <i>Globigerina</i> sp. cf. <i>G. belli</i> White; Sample G 64; 1a dorsal view, 1b ventral view; 65 $\times$ .	100
2. <i>Globigerina voluta</i> White; Sample Q 12; 61 $\times$ .	100
3a-c. <i>Cibicides praecursorius</i> (Schwager); Sample Q 12; 3a dorsal view, 3b ventral view, 3c peripheral view; 95 $\times$ .	101
4a-c. <i>Cibicides praecursorius</i> (Schwager) var. <i>scrobiculata</i> (Schwager); Sample Q 12; 4a dorsal view, 4b ventral view, 4c peripheral view; 65 $\times$ .	102
5a-c. <i>Cibicides praecursorius</i> (Schwager) var. <i>umbonifera</i> (Schwager); Sample C 267; 5a dorsal view, 5b ventral view, 5c peripheral view; 65 $\times$ .	102
6a-c. <i>Anomalina midwayensis</i> (Plummer); Sample Q 3; 6a dorsal, 6b ventral, 6c peripheral view; 65 $\times$ .	102
7a-c. <i>Anomalina midwayensis</i> (Plummer) var. <i>trochoidea</i> (Plummer); Sample G 64; 7a dorsal view, 7b ventral view, 7c peripheral view; 65 $\times$ .	102
8a-c. <i>Anomalina newmanae</i> (Plummer) var. <i>ksobensis</i> Drooger, n. var.; Sample 699; holotype; 8a dorsal view, 8b ventral view, 8c peripheral view; 65 $\times$ .	102
9a-c. <i>Laffitteina bibensis</i> Marie; Sample C 265; 9a dorsal view, 9b ventral view, 9c peripheral view; 17 $\times$ ; 11, 12 median sections through dorsal sides of whorls showing canal systems and pores; 13 median section just below dorsal surface of test; 14, 15 transverse sections showing involute character of the walls and traces of the spiral canal system; 11-13 approx. 24 $\times$ ; 14 and 15 approx. 32 $\times$ .	99
10a-c. <i>Laffitteina conica</i> Drooger n. sp.; Sample C 267; holotype; 10a dorsal view, 10b ventral view, 10c peripheral view, 33 $\times$ . 16 median section, 17 transverse section, both figs. approx. 39 $\times$ .	100
18, 19. <i>Omphalocyclus macropora</i> (Lamarck); Sample C 265; 18, median section; 19 transverse section, both figs. approx. 19 $\times$ .	103

pl. 12, f. 4) from the Miocene of Florida and with *B. thomsoni* Howe (1939, Louis. Dept. Conserv., Geol. Survey, Bull. 14, p. 69, pl. 9, f. 17) from the Claiborne Eocene of Louisiana. *B. crenulata* Loetterle (non Cushman) (1937, Nebraska Geol. Survey, ser. 2, Bull. 12, p. 38, pl. 6, f. 1) from the Upper Cretaceous Niobrara formation has much higher early chambers than the Algerian species.

The species has been named in honour of G. Bétier, Inspecteur Général des Mines, Directeur du Service de la Carte Géologique de l'Algérie.

*Occurrence*—Common to abundant in C 263.

Genus *Loxostomum* Ehrenberg, 1854

*Loxostomum plaitum* (Carsey)

*Bolivina plaita* CARSEY, 1926, Univ. Texas Bull. 2612, p. 26, pl. 4, f. 2.

*Loxostoma plaita* (Carsey) CUSHMAN, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 169, pl. 20, f. 1-4.

*Occurrence*—A single distinct specimen in C 263.

Originally described from the Lower Navarro of Texas. Widely distributed in the Upper Taylor and Navarro of the United States.

Genus *Siphogenerinoides* Cushman, 1927

*Siphogenerinoides parvus* Cushman

Plate 15, figure 31

*Siphogenerinoides parva* CUSHMAN, 1929, Contrib. Cushman Lab. Foram. Res., vol. 5, p. 58, pl. 9, f. 11-13; STONE, 1946, Journ. of Pal., vol. 20, p. 471, pl. 71, f. 11, 12.

*Remarks*—As far as could be ascertained the aperture in our specimens is arcuate, usually with a slight neck and a thickened rim. In the larger individuals the bi- (tri-) serial portion of the test is relatively small, even smaller than in the pictured American specimens. A drawing is given of one of the small specimens from our material (Pl. 15, fig. 31).

*Occurrence*—Few in Q 3.

Originally described from the Upper Cretaceous Colon shale of Venezuela.

Family ROTALIIDAE

Genus *Valvulineria* Cushman, 1926

*Valvulineria koenigswaldi* Drooger, n. sp.

Plate 15, figures 32a-33c

*Description*—Test small, trochoid, compressed, about equally biconvex; periphery rounded, slightly lobulate in the later portion; chambers distinct, somewhat inflated, especially in the adult, rapidly increasing in size as added, about two whorls visible dorsally, 7-9 chambers in the final convolution; sutures ventrally depressed and evenly curved, radiating from the small umbilical depression, dorsally depressed and curved, the spiral sutures being most strongly depressed; wall smooth and finely perforate; aperture somewhat variable and often indistinct, usually consisting of a nar-

row slit along the inner margin of the final chamber from the periphery to about half way towards the ventral umbilicus, with a curved narrow opening from about the middle of the basal slit, extending obliquely upwards into the apertural face and pointing to the ventral umbilicus. Larger diameter up to 0.85 mm., thickness up to 0.35 mm.

*Remarks*—In many specimens only the oblique opening of the aperture is distinct, whereas in others this part could not be traced. Sometimes it is less well-developed and evidently it is replaced then by a shallow closed furrow in the apertural face. Similar apertures occur in some described species of the genus *Valvulineria*, for which reason our species is placed here although distinct umbilical plates of the chambers are hardly developed, if not entirely lacking. The peculiar apertural characteristics of this species make its generic placement uncertain. In some respects the specimens resemble compressed *Gyroidina* species, whereas on the other hand the extension of the aperture towards the periphery seems to place this form in the vicinity of the *Anomalinidae*. A similar species in general appearance is *Gyroidina childsi* Martin (1943, Publ. Stanford Univ., Calif., Univ. Ser., Geol. Sci., vol. 3, no. 3, p. 112, pl. 6, f. 6) from the Eocene and Paleocene Lodo formation of California, which is different from *V. koenigswaldi* in its slightly higher number of less elongate chambers, whereas the aperture is evidently a simple basal slit in this American species.

The species has been named in honour of G. H. R. von Koenigswald, Professor of Paleontology of the State University of Utrecht.

*Occurrence*—Common in 699 and G 64, few in Q 1 and C 263, rare in R 109. Holotype and paratype from G 64.

*Valvulineria palmi* Drooger, n. sp.

Plate 15, figures 34a-35c

*Description*—Test small, trochoid, about equally biconvex; periphery broadly rounded and lobulate; chambers inflated, rather rapidly increasing in size as added, each with a slight extension over the small depressed ventral umbilicus, dorsally two whorls visible, about 5 chambers in the final coil; sutures depressed, curved; wall finely granular and coarsely perforate; aperture ventral, at the base of the last-formed chamber as a low arched slit from near the periphery to close to the umbilicus. Diameter up to 0.20 mm., thickness up to 0.13 mm.

*Remarks*—Except for its much smaller size *V. palmi* differs from *V. chirana* Cushman and Stone (1947, Cushman Lab. Foram. Res., Spec. Publ. 20, p. 22, pl. 3, f. 3) from the Upper Eocene of Peru, by its generally more curved sutures, whereas *Gyroidina byramensis* Cushman and Todd (1946, Contrib. Cushman Lab. Foram. Res., vol. 22, p. 98, pl. 16, f. 19-21) from the Oligocene Byram marl of Mississippi is somewhat more elongate and evidently possesses a flattened dorsal side.



*Occurrence*—Few in Q 12. In C 263 some rare specimens were encountered, which are close to *V. palmi*, only being relatively somewhat thicker with a wider aperture.

Genus *Rotalia* Lamarck, 1804

*Rotalia sigali* Drooger, n. sp.

Plate 15, figures 36a-37c

*Description*—Test small, trochoid, unequally biconvex to plano-convex, dorsal side most strongly elevated, forming a low, somewhat rounded cone, ventral side occasionally slightly convex, usually about flat; periphery subacute, formed by the thick peripheral part of the spiral wall, in some specimens with a beginning development of peripheral spines; ventral umbilicus filled with a large plug, somewhat variable in size, generally separated from the inner ends of the chambers, especially the later ones, by a deeply depressed furrow; chambers rather distinct, about three whorls visible dorsally, 8-11 chambers in the final convolution; dorsal sutures strongly oblique and somewhat curved, limbate, slightly raised in the early part of the test to slightly depressed in the adult; ventral sutures depressed, becoming deeper and wider towards the umbo, where they open into the umbilical furrow, radial to slightly tangential to the umbo, slightly curved, more strongly so near the periphery, where they often show a more or less developed bifurcation; wall smooth, perforate; aperture ventral at the base of the last-formed chamber, running from near the periphery to close to the umbo, in well-preserved specimens covered by a narrow, plate-like structure. Diameter up to 0.45 mm., thickness up to 0.18 mm.

*Remarks*—No clear thin sections of this small species could be made.

*R. sigali* shows morphologically some resemblance with *R. orientalis* Cushman and Bermudez (1947, Contrib. Cushman Lab. Foram. Res., vol. 23, p. 26, pl. 7, f. 2) from the Upper Eocene of Cuba and *R. cushmani* Applin and Jordan (1945, Journ. of Pal., vol. 19, p. 143) from the Upper Eocene of Florida. Since little is remarked about the variation of these species, it is impossible to obtain a clear comparison of the Algerian with the American forms. Some extreme variants of *R. sigali* approach the types of each of these species, but both from the figures and from the descriptions it is evident that many differences exist with the group of individuals from the Hodna Mountains. For this reason the latter is described as a new species. Bifurcating sutures and peripheral spines are shown in much higher development than in *R. sigali* in *R. lithothamnica* Uhlig (1886, Jahrb. Geol. Reichsanst., Wien, vol. 36, p. 195, pl. 5, f. 9-11) from the Lower Tertiary of the Carpathians.

*Occurrence*—Common in C 265, few in C 267. Holotype and paratype from C 265.

Genus *Laffitteina* Marie, 1945

*Laffitteina bibensis* Marie

Plate 16, figures 9a-c; 11-15

*Laffitteina bibensis* MARIE, 1945, Bull. Soc. Géol. France, ser. 5, vol. 15, p. 431, f. 1-3, 14-16, pl. 1, f. 1-6.

*Remarks*—The specimens of the Hodna material agree fairly well with those described by Marie. A few additional, partly differing, observations could be made on the inner structure.

In thin sections a canal system in the walls is apparent, which is best visible in the septae. This intraseptal system consists of fissure-like spaces in the septae, which send branches, either bifurcating or not, to the surface of the test, where they correspond with the openings along the sutures. In the central part of the test many of these canals, leading to the surface, are seen to pierce the involute later walls without interruption. A second, much less distinct canal system occurs on the dorsal side of the spiral walls of the earlier convolutions, where these are covered by the later whorls. This system, which is formed on the older spiral wall by an irregular covering with shell material from the chambers of the overlying whorls, consists of a number of thin, sometimes flattened, irregular and anastomosing, spirally arranged canals. In some of the sections the latter are distinctly seen to correspond with the intraseptal canals of the previous and overlying whorls. The spiral system is probably only developed on the dorsal part of the coils and it is absent in the final whorl.

When regarding the exterior, *Laffitteina* seems to be close to the genus *Faujasina* Orbigny, 1839, as was suggested by Marie. According to d'Orbigny (1846, Foram. Foss. Bass. Tert. Vienne, p. 194, pl. 21, f. 29-31) the type species of the latter genus, *Faujasina carinata*, had been derived from the Upper Cretaceous of Maastricht, Holland. Cushman remarked, however, (1939, U. S. Geol. Survey, Prof. Paper 191, p. 67) that this statement is probably erroneous, as *Faujasina carinata* occurs in the Pliocene of St. Erth in southern England, but has never again been found at Maastricht. An examination of material from St. Erth evidenced that the specimens from this English locality, which are completely identical with those pictured by d'Orbigny, belong to a thin-walled species, obviously closely related to recent species of *Elphidium*. When assuming very close relations between *Laffitteina bibensis* and *Faujasina carinata* we would have to conclude a wide, incomprehensible time-stratigraphic gap between the occurrences of both genera. Therefore it looks unlikely that *Faujasina* is connected directly with *Laffitteina*, their resemblance obviously being only superficial. It is worth mentioning moreover, that, according to Hofker (1928, Contrib. Cushman Lab. Foram. Res., vol. 4, p. 80), the species from St. Erth shows an

umbilical canal system on either side of the test, in addition to that in the septae (as is the case in *Elphidium*), which is principally different from the systems observed in the Algerian *Laffitteinae*.

On the other hand connections of *Laffitteina* with some species of *Rotalia* s. l. are thought to be much closer, for which reason the genus is considered to belong to the *Rotaliidae*, rather than to the *Nonionidae*. Clear comparisons, however, are difficult, because of lack of sufficient data on the interior characters of the *Rotalia* species. Other difficulties are caused by the confusion in literature about the generic placement of many of these species. Some of the species described as *Rotalia* (*R. schroeteriana* Parker and Jones, *R. elphidioides* Caudri, *R. catelliformis* Thalmann, *R. papillosa* var. *tuberculata* Schubert, *R. viennoti* Greig a. o.) either possess bifurcating intraseptal canals or distinct openings in the sutural lines or both. However, the larger part of these species are much younger than the *Laffitteina* species. The latter differ from them by the absence of a distinct umbilical filling with plug or pillars, the involute character of the spiral walls at the dorsal side and probably also by the possession of a spiral canal system on the dorsal side of the earlier whorls, instead of a ventral umbilical system, as was described for some *Rotalia* species (f. i. *R. schroeterina*) by Hofker (1927, Foraminifera of the Siboga Expedition). Possibly *Laffitteina* is most closely related to *Sulcoperculina* Thalmann, 1938, though it lacks the distinct peripheral groove of the latter.

*Occurrence*—Common in C 265.

Originally described from the Montian of northern France. In Algeria the species possibly ranges downwards into the Upper Cretaceous.

***Laffitteina conica* Drooger, n. sp.**

Plate 16, figures 10a-c; 16, 17

*Description*—Test trochoid, planoconvex, dorsally flat, ventrally conical, on the dorsal side strongly evolute, on the ventral side involute or nearly so; periphery subacute to narrowly rounded; chambers not inflated, numerous, about 17 in the final coil in specimens of about 0.7 mm. diameter, about 24 in those of a diameter of 1.1 mm.; chamber walls involute on both sides; sutures straight to moderately curved, more or less limbate, with openings, either in or along the sutures, only occasionally with a row on each side of the sutural lines; in the central part of the test, especially on the dorsal side, the openings are irregularly placed; wall thick, finely perforate; aperture not visible from the outside, probably a slit at the base of the final chamber's apertural face. Maximum observed diameter 1.2 mm.

As far as could be ascertained the canal systems are the same as in *L. bibensis*; only the ascending branches of the intraseptal fissures usually do not bifurcate before reaching the surface of the test.

*Remarks*—Occasionally the dorsal side of the test is very slightly convex; the ventral cone varies in relative height from one quarter to over half the diameter of the test. As in *L. bibensis* the cavities in the interior of the specimens are filled with reddish brown coloured material, but to a considerably lesser degree, which made it more difficult to establish the characters of the canal systems than in *L. bibensis*.

*L. conica* differs from *L. bibensis* by the smaller size of adult specimens, the planoconvex test, which is much more trochoid, and the rarely bifurcating of the branches of the intraseptal fissures. It occurs in the same section, only at a higher level. It is very likely that it descended directly from the earlier species. As in none of both occurrences specimens were found, which are morphologically distinctly intermediate between both groups of individuals, the younger group is treated as a separate species. Certain variants of *L. monodi* Marie resemble *L. conica*, but in the latter no traces of irregular coiling were found.

*Occurrence*—Common in C 267.

**Family GLOBIGERINIDAE**

**Genus *Globigerina* Orbigny, 1826**

***Globigerina* sp. cf. *G. belli* White**

Plate 16, figures 1a, b

*Globigerina belli* WHITE, 1928, Journ. of Pal., vol. 2, p. 197, pl. 28, f. 5.

*Remarks*—Our few specimens, which show only a superficial resemblance with White's species, to which they are tentatively referred to, are too scarce and too ill-preserved for a safe determination.

*Occurrence*—Rare in G 64.

Reported from the Uppermost Mendez and the Lower Velasco of Mexico.

***Globigerina voluta* White**

Plate 16, figure 2

*Globigerina voluta* WHITE, 1928, Journ. of Pal., vol. 2, p. 197, pl. 28, f. 5; DROOGER, 1951, Proc. Kon. Ak. Wetensch., Amsterdam, ser. B, vol. 54, no. 1, p. 69, f. 8.

*Globigerina* cf. *cretacea* SCHWAGER (non d'Orbigny), 1883, Palaeontogr., vol. 30, pt. 1, Pal. Theil., p. 119, pl. 29, f. 13.

*Remarks*—In the stratigraphically lower samples from the Hodna Mountains most specimens, considered to belong to *G. voluta*, are identical with the one pictured by White but some smaller individuals are closer to *G. aspera* (Ehrenberg). Possibly *G. voluta* may be considered to be identical with *G. aspera*, as for instance described and pictured by Brotzen (1936, Sver. Geol. Unders., Avh., ser. C, no. 396, årsb. 30, p. 170, pl. 13, f. 2), but the typical forms in our material are completely smooth, whereas in the Algerian specimens the chambers are more rapidly increasing in size than in typical *G. aspera*. At higher levels (G 64,



Q 3) the few observed individuals show intermediate features between *G. voluta*, *G. cretacea* Orbnigay, and *G. pseudo-bulloides* Plummer.

*Occurrence*—Few in Q 12 and C 263, rare in Q 3, C 265 and G 64.

This species has mainly been reported from Upper Senonian strata, but, according to White, its range in Mexico extends into the basal Velasco. A nearly identical form has been pictured by Schwager from the Paleocene of Egypt.

#### *Globigerina pseudo-bulloides* Plummer

*Globigerina pseudo-bulloides* PLUMMER, 1926, Univ. Texas Bull. 2644, p. 133, pl. 8, f. 9; GLAESSNER, 1937, Probl. Paleont., Moscow Univ., vols. 2-3, p. 382, pl. 4, f. 31; CUSHMAN and TODD, 1942, Contrib. Cushman Lab. Foram. Res., vol. 18, p. 43, pl. 8, f. 3, 4.

*Remarks*—The scarcely observed Algerian specimens usually show only four chambers in the final whorl, thus closely resembling those pictured by Cushman and Todd from the Naheola formation of Alabama.

*Occurrence*—Rare in 699.

This species is known from several widely distributed localities of Lowermost Tertiary age.

#### *Globigerina* sp. cf. *G. velascoensis* Cushman

*Globigerina velascoensis* CUSHMAN, 1925, Contrib. Cushman Lab. Foram. Res., vol. 1, p. 19, pl. 3, f. 6; CUSHMAN, 1926, Bull. Am. Ass. Petr. Geol., vol. 10, no. 6, p. 605, pl. 20, f. 21; WHITE, 1928, Journ. of Pal., vol. 2, p. 196, pl. 28, f. 2.

*Remarks*—Our rare specimens most closely resemble those pictured by White. Partly they are thicker than the one pictured together with Cushman's original description.

*Occurrence*—Rare in G 64.

*G. velascoensis* is reported as a typical species for the Mexican Velasco formation.

#### Family GLOBOROTALIIDAE

##### Genus *Globorotalia* Cushman, 1927

##### *Globorotalia wilcoxensis* Cushman and Ponton var. *acuta* Toulmin

*Globorotalia wilcoxensis* Cushman and Ponton var. *acuta* TOULMIN, 1941, Journ. of Pal., vol. 15, p. 608, pl. 82, p. 6-8; CUSHMAN and RENZ, 1942, Contrib. Cushman Lab. Foram. Res., vol. 18, p. 12, pl. 3, f. 2.

*Occurrence*—In G 64 a single distinct specimen with four chambers in the final whorl is recorded to belong to this variety.

*G. wilcoxensis* var. *acuta* has originally been described from the Wilcox Lower Eocene of Alabama. As several closely allied forms range from the top of the Senonian upwards, no stratigraphical conclusions

can be drawn from our single specimen, because of lack of sufficient material.

#### Family ANOMALINIDAE

Numerous representatives of this family were observed in the samples of the Algerian Cretaceous-Tertiary transitional strata of the northern border of the Hodna Basin. The individuals in each of the samples show a rather wide variation and the ranges of variation of the specimens of the different samples overlap in most cases. Thus it proved to be impossible to draw sharp boundaries between species, although on the other hand minor changes, occurring in the group from the base of the ideal section upwards, might be too important for stratigraphy to be neglected and to treat the entire group as a single species without subdivision. For the specific determination a choice had to be made out of numerous described and closely resembling species, which are often much less apart from one another than the individuals of one of our samples, which doubtlessly belong together. Of each of the forms, dealt with separately, only a single, more or less typical, specimen has been pictured, as it was impossible to show the existing variation by means of sufficient numbers of figures.

#### Genus *Cibicides* Montfort, 1808

##### *Cibicides praecursorius* (Schwager)

Plate 16, figures 3a-c

*Discorbina praecursoria* SCHWAGER, 1883, Palaeontogr., vol. 30, pt. 1, pal. pt., p. 125, pl. 27, f. 12, 13, pl. 29, f. 16.

*Cibicides praecursorius* (Schwager) GLAESSNER, 1937, Prob. Paleont., Moscow Univ., vols. 2-3, p. 386, pl. 5, f. 40.

*Remarks*—Especially the smaller specimens from the stratigraphically lower samples may be assigned to this species, but usually the following two varieties are equally well represented or even more abundant, as well as many intermediates. In the individuals of the species and of its two varieties, the dorsal side is usually somewhat less flattened than in those pictured from Egypt, thus tending towards *Anomalina midwayensis* (Plummer) and its variety (see below). Part of the specimens also somewhat resemble *C. mortoni* (Reuss) (1862, Sitzungsber. K. Ak. Wiss., Wien, Math. Naturw., vol. 44, pt. 1, p. 337, pl. 8, f. 1) from the Senonian of New Jersey, U. S. (compare Pl. 16, fig. 3).

Though several occurrences of *C. praecursorius* are given in literature, it may be doubted whether all these belong to Schwager's species. Our specimens are closest to those pictured by Schwager and Glaessner.

*Occurrence*—*C. praecursorius* itself is relatively most common in Q 12 and C 263. In C 265, and especially in C 267, the variety *umbonifera* is predominant, whereas the variety *scrobiculata* occurs in all these

samples, but in the higher ones the features are mixed with those of var. *umbonifera*.

Originally described from the Paleocene of Egypt. Recorded from the Paleocene of the Caucasus, as well as from some Early Tertiary deposits in America, in which there may partly be incorrect interpretations of this species.

*Cibicides praecursorius* (Schwager)

var. *scrobiculata* (Schwager)

Plate 16, figures 4a-c

*Anomalina scrobiculata* SCHWAGER, 1883, *Palaeontogr.*, vol. 30, pt. 1, pal. pt., p. 129, pl. 29, f. 18.

*Remarks*—All intermediate forms between typical specimens of *C. praecursorius* and this variety are present. Also intergradation occurs with *Anomalina midwayensis* (Plummer) and its variety, both described below. Morphologically *C. praecursorius* var. *scrobiculata* rather belongs to *Anomalina* than to *Cibicides*, but it has been placed in the latter genus here for its distinct connections with *C. praecursorius*. The place of the aperture is not clear from Schwager's description and figures, but it is unlikely that the form, referred to as *Valvulineria scrobiculata* (Schwager) by Cushman and Ponton from the Wilcox Eocene of Alabama (1932, *Contrib. Cushman Lab. Foram. Res.*, vol. 8, p. 70, pl. 9, f. 5) is identical with the Egyptian species.

*Occurrence*—See *C. praecursorius*.

Originally described from the Paleocene of El-Guss-Abu-Said, Egypt.

*Cibicides praecursorius* (Schwager)

var. *umbonifera* (Schwager)

Plate 16, figures 5a-c

*Discorbina umbonifera* SCHWAGER, 1883, *Palaeontogr.*, vol. 30, pt. 1, pal. pt., p. 126, pl. 27, f. 14.

*Remarks*—Several specimens with the characteristics of this variety were recognized among our material. Partly they differ from the one, pictured by Schwager, by a stronger excess of shell material in the ventral umbilicus, while others again have hardly depressed sutures in the larger part of the test.

*Occurrence*—See *C. praecursorius*.

As both previously mentioned forms this variety has originally been described from the Paleocene beds of El-Guss-Abu-Said, Egypt.

Genus *Anomalina* Orbigny, 1826

*Anomalina midwayensis* (Plummer)

Plate 16, figures 6a-c

*Truncatulina midwayensis* PLUMMER, 1926, *Univ. Texas Bull.* 2644, p. 141, pl. 9, f. 7, pl. 15, f. 3.

*Anomalina midwayensis* (Plummer) CUSHMAN, 1940, *Contrib. Cushman Lab. Foram. Res.*, vol. 16, p. 73, pl. 12, f. 18.

*Anomalinoides midwayensis* (Plummer) BROTZEN, 1948,

*Sver. Geol. Unders.*, Avh. ser. C, no. 493, årsb. 42, no. 2, p. 88, pl. 14, f. 3.

*Remarks*—The specimens, regarded to belong to *A. midwayensis*, show close affinities to the *C. praecursorius* group, described above. Although highly variable, as for instance by the nearly planoconvex appearance of the test in many cases or the slight development of umbilical knobs and the generally less raised sutures in others, the majority of our specimens are so close to the earlier pictured representatives of *A. midwayensis* (Plummer) to justify the determination.

*Occurrence*—Common in Q 3.

Originally described from the Midway formation of Texas. Reported by Brotzen from the Paleocene of Sweden.

*Anomalina midwayensis* (Plummer)

var. *trochoidea* (Plummer)

Plate 16, figures 7a-c

*Truncatulina midwayensis* Plummer var. *trochoidea* PLUMMER, 1926, *Univ. Texas Bull.* 2644, p. 142, pl. g, f. 8.

*Remarks*—A number of specimens from sample G 64 are close to this Midway form, but usually they have the raised character of the sutures confined to the early portion of the test, whereas the later chambers are somewhat more inflated than in the typical, corresponding with a more lobulate periphery. The evolute portion of the test is differently developed in the specimens of this sample, on the average being half way in this feature between typical forms of *A. midwayensis* (Plummer) and this variety. On the other hand intermediates are present in G 64 between this variety and the new *A. newmanae* var. *ksobensis* (see below), of which some representatives were found in this sample, too. The diversity of forms in the sample from El Melab may partly be due to the fact that G 64 is a composite sample from slightly above, slightly below and in the *Cardita beaumonti* layer.

Except for the smaller size of the second form, there are no clear differences between *A. midwayensis* var. *trochoidea* and *Truncatulina welleri* Plummer (1926, *Univ. Texas Bull.* 2644, p. 143, pl. 9, f. 6) from the Texas Upper Midway, as far as can be concluded from the pictures given by Plummer.

*Occurrence*—Rather common in G 64.

Originally described from the basal Midway of Texas.

*Anomalina newmanae* (Plummer)

var. *ksobensis* Drooger, n. var.

Plate 16, figures 8a-c

*Description*—Variety differing from the typical in having the sutures limbate and raised, especially on the convex side. Diameter up to 0.35 mm.

*Remarks*—*A. newmanae* var. *ksobensis* is the least variable and morphologically most distinct form of all *Anomalinidae*, encountered in the samples from the Northern Hodna Mountains. Most of its specimens



from stratigraphically higher samples can easily be distinguished; only in G 64 individuals occur with characteristics intermediate between those of this new variety and the other mentioned forms, especially *A. midwayensis* var. *trochoidea*. *A. newmanae* var. *ksobensis* is placed in the genus *Anomalina* for these evident relations with the other representatives of the family *Anomalinidae*, found in the stratigraphically lower samples. The Algerian specimens were combined as a new variety to *A. newmanae* (Plummer) (*Discorbis newmanae* Plummer, 1926, Univ. Texas Bull. 2644, p. 138, pl. 9, f. 4) for the striking resemblance between both forms, though the kind of relations between them is unknown.

**Occurrence**—Common in 699, rare in Q 1 and G 64. Holotype from 699.

*A. newmanae* has been described from the basal Midway of Texas.

### Family ORBITOIDIDAE

Genus *Omphalocyclus* Bronn, 1852

*Omphalocyclus macropora* (Lamarck)

Plate 16, figures 18, 19

*Orbulites macropora* LAMARCK, 1816, Hist. nat. Animaux sans vertèbres, tome 2, p. 197.

*Omphalocyclus macropora* (Lamarck) DOUVILLÉ, 1920, Bull. Soc. Géol. France, sér. 4, tome 20, p. 230, pl. 8, f. 5-9, text figs. 35-37; HOFKER, 1949, Verh. Kon. Belg. Inst. Natuurw., no. 12, p. 60, f. 23; VISSER, 1950, Leidse Geol. Meded., vol. 16, p. 294, pl. 9, f. 2, pl. 11, f. 7, 8.

*Sporadotrema minutum* HOFKER, 1926, Natuurh. Maandblad, p. 62, f. 1-20.

**Remarks**—A number of specimens from C 265 with a maximum observed diameter of 2.6 mm. appear to be identical with this well-known species, reported from several European Upper Cretaceous deposits.

**Occurrence**—Few in C 265.

Visser lists occurrences from Holland, Italy, Switzerland and Greece, all of which are of Upper Cretaceous, mainly Maastrichtian, age. At Maastricht the species is found in the uppermost part of the Maastrichtian (Md). Thus it may be considered possible that it ranged elsewhere, i. e. in North Africa, still higher into the stratigraphical column, as other distinct Maastrichtian markers (except possibly *Siphogenerinoides parva* Cushman) are lacking in the investigated Algerian assemblages. Also Rey (1948, in Flandrin, p. 155) mentions the occurrence of *O. macropora* from the Danian of Algeria.

### REFERENCES

- DROOGER, C. W. and VOUTÉ, C., 1951, Sur la présence d'Inocérames dans un niveau post-maastrichtien près d'Aïn Fakroun (Algérie), Bull. Soc. Géol. France, (6), vol. 1, pp. 313-317.
- FLANDRIN, J., 1948, Contribution à l'Etude stratigraphique du Nummulitique Algérien, Bull. Serv. Carte Géol. Algérie, sér. 2, no. 19.
- SAVORNIN, J., 1920, Etude géologique de la région du Hodna et du Plateau sétifien, Bull. Serv. Carte Géol. Algérie, sér. 2, no. 7.
- SIGAL, J., 1949, Dano-Montien ou Paléocène ? ou le passage du Crétacé au Tertiaire en Algérie, C. R. somm., Soc. Géol. France, no. 8, 25 avril, pp. 150-152.
- wayina (genotype *Discorbis multisectus* Galloway and Heminway) and two other species, one new.
- COLOM, GUILLERMO. Micropaleontología aplicada. Estudio del sondeo profundo de Oliana (provincia de Lérida).—Bol. Instit. Geol. Min. España, vol. 63, 1951, pp. 1-52, pls. 1-8, text figs. 1-6, 3 distribution tables.—An Eocene fauna from a deep well is studied and mostly illustrated, and the ranges of species graphically shown.
- CUSHMAN, JOSEPH A. Paleocene Foraminifera of the Gulf Coastal Region of the United States and adjacent areas.—U. S. Geol. Survey Prof. Paper 232, 1951 (Jan. 29, 1952), 75 pp., 24 p.s.—About 280 species and varieties are recorded and illustrated. One new name is assigned. Geographic distribution charts are included.
- DAVIS, A. G. *Howchinia bradyana* (Howchin) and its distribution in the Lower Carboniferous of England.—Proc. Geologists' Assoc., vol. 62, pt. 4, 1951, pp. 248-253, pls. 10, 11.—A re-description and re-figuring with additional information on localities.
- ANDRUSOV, D. Skameneliny Karpatskykh Druhohôr. I. Rastliny a Prvoky. (Les Fossiles du Mésozoïque des Karpates. I. Plantes et Protozoaires).—Práce Státného Geologického Ústavu, No. 25, 1950, pp. 1-164 (pp. 122-164 in French), pls. 1-27, text figs. 1, 2.—Specimens are recorded and illustrated in section from material of Lias to Senonian age.
- ASANO, KIYOSHI. Illustrated Catalogue of Japanese Tertiary Smaller Foraminifera (compiled and edited by Leo. W. Stach).—Tokyo, Japan, Part 15: Lagenidae, Dec. 18, 1951, pp. 1-39, text figs. 1-165.—Concluding the series, 114 species and varieties, none new, are described and illustrated, and one is given a new name.
- BERMUDEZ, PEDRO J. *Heminwayina*, un genero nuevo de los Foraminiferos rotaliformes, y sus especies.—Mem. Soc. Ciencias Nat. La Salle, vol. 11, No. 30, Sept.-Dec. 1951, pp. 325-329, text figs. 1-9.—*Hemin-*

- DROOGER, C. W. Foraminifera from the Tertiary of Anguilla, St. Martin and Tintamarre (Leeward Islands, West Indies).—*Proc. Kon. Nederl. Akad. Wetenschappen*, ser. B, vol. 54, No. 1, 1951, pp. 54-65, text figs. 1-4.—Foraminifera are listed and a few species are illustrated, with one new variety being described.
- Upper Cretaceous Foraminifera of the Midden-Curacao beds near Hato, Curacao (N.W.I.).—*Proc. Kon. Nederl. Akad. Wetenschappen*, ser. B, vol. 54, No. 1, 1951, pp. 66-72, 1 pl., map.—Ten species are recorded and illustrated, none new.
- Notes on some representatives of *Miogypsinella*.—*Proc. Kon. Nederl. Akad. Wetenschappen*, ser. B, vol. 54, No. 4, 1951, pp. 357-365, text figs. 1-7.—Two species, one new, are described and illustrated from the Oligocene of Cuba and Trinidad.
- GRIMSDALE, T. F. Correlation, age determination, and the Tertiary pelagic Foraminifera.—*Proc. Third World Petr. Congress*, sec. 1, 1951, pp. 463-472, text fig. 1 (range chart).—An important paper discussing and charting the ranges of 41 pelagic species, comparing their stratigraphic ranges in the Middle East and the Western Hemisphere.—Followed on pp. 472-475 by Appendix I—Note on the pelagic Foraminifera in the Blue Marls of Biarritz, France; Appendix II—On a sample of upper Lutetian from Grande Carrière, Las-salle, Landes, France; Appendix III—Note on Taxonomic procedure for micropaleontologists; and Discussion.
- HOFKER, J. The Foraminifera of the Siboga Expedition, Part III, Ordo Dentata . . . Rotalidae, Siboga-Exped., Mon. IVa, 1951, pp. 1-513, text figs. 1-348.—Fifty-three genera are treated, of which 17 are proposed as new. In at least three instances, the new genus is erected on the basis of a species which is the genotype of an already existing genus, in disregard for the Rules of Nomenclature. Two genera, *Bifarina* and *Bolivinita*, are discarded. Twenty-two species are described as new. Careful descriptions of the internal structures and the foramina are included.
- KITAZAKI, UMEKA, MASAHO MARUHASI, and REIKO HUSEZIMA. Studies on the foraminiferal fauna from the boring cores near Kashiwazaki Oil-field, Niigata-ken.—*Japanese Journ. Geol. Geogr.*, Trans., vol. 21, Nos. 1-4, Nov. 1, 1949, pp. 135-153, text figs. 1-3.—Changes in percentage composition of foraminiferal faunas, indicating facies changes, throughout the wells are graphically represented, and correlations between the wells are shown.
- KOCHANSKY-DEVIDÉ, VANDA. Sur la présence du genre *Globotruncana* dans les Calcaires des environs de Bor en Serbie Orientale.—*Inst. Géol. Univ. Beograd. Ann. Géol. de la Pénin. Balkan.*, vol. 19, 1951, pp. 113-117, pl. 1.—A single form of this genus is recorded and illustrated and the beds assigned to Senonian age.
- KONISHI, KENJI. Permian microfossils in the Dodo conglomerate of the Yasubatype.—*Trans. Proc. Paleont. Soc. Japan*, n. ser., No. 5, Feb. 15, 1952, pp. 155-165, 1 text fig.—Seven fusulinids, none new, are recorded and illustrated.
- LOWMAN, SHEPARD W. The relationship of the biotic and lithic facies in Recent Gulf Coast sedimentation.—*Journ. Sedimentary Petrology*, vol. 21, No. 4, Dec. 1951, pp. 233-237.—Recent foraminiferal facies in the Gulf are used to illustrate relationships.
- MARKS, P. JR. *Arenonionella*, a new arenaceous genus of Foraminifera from the Miocene of Algeria.—*Proc. Kon. Nederl. Akad. Wetenschappen*, ser. B, vol. 54, No. 4, 1951, pp. 375-378, text figs. 1-4.—*Arenonionella* (genotype *A. voutel* n. sp.) is placed in the subfamily Haplophragminae.
- POKORNY, VLADIMIR. Mikrofauna eocennih zeleného jilu z Nikolcic.—*Rozpravy Ceske Akad. ved a umeni*, Trida II, Rocnik 59, 1949, cast II, cislo 15, 1950, pp. 1-39, 1 pl.—Forty-nine species are recorded, a few figured, none new.
- SELLIER DE CIVRIEUX, JEAN MARC. Ocurrence del género *Globivalvulina* en el Permiano de Venezuela.—*Bol. Geol. Venezuela Ministerio de Minas e Hidrocarburos*, vol. 1, No. 1, April-June 1951, pp. 143-146, 1 pl., 2 diagrams.—Ten species of the genus are compared diagrammatically as to stratigraphic distribution and maximum diameter.
- Ocurrencia en Venezuela de *Trocholina arabica* Henson.—*Bol. Geol. Venezuela Ministerio de Minas e Hidrocarburos*, vol. 1, No. 2, July-Sept. 1951, pp. 223-228, pl. 1, text fig. 1 [map].
- SHINOHARA, I. Illustrated catalogue of fossils from Shikoku, Japan.—Tokyo, 11 pp., pls. 1-13, map.—A few fusulinid foraminifera are illustrated on two plates.
- THALMANN, HANS E. Bibliography and index to new genera, species and varieties of Foraminifera for the year 1950.—*Journ. Pal.*, vol. 26, No. 2, March 1952, pp. 223-268.
- TOULMIN, L. D., P. E. La MOREAUX, and C. R. LAN-PHERE. Geology and Ground-water Resources of Choctaw County, Alabama.—*Geol. Survey Alabama Spec. Rept. 21 and County Rept. 2*, 1951, 197 pp., 11 pls., 23 text figs., 4 tables, 2 maps.—Thirty-nine Foraminifera are listed from the Nanafalia formation.
- VAN VOORTHUYSEN, J. H. Recent (and derived Upper Cretaceous) Foraminifera of the Netherlands Wadden Sea (tidal flats).—*Mededel. Geol. Stichting*, n. ser., No. 5, 1951, pp. 23-32, pls. 1, 2, map, tables.—Fifty-eight species and varieties of indigenous forms, one variety new, plus 7 species of derived forms were found. Notes on quantitative distribution and ecologic significance are included.
- The quantitative distribution of the Holocene Foraminifera in the N. O. Polder.—*Proc. Third Internat. Congress of Sedimentology*, Groningen-Wageningen, Netherlands, 5-12 July 1951, pp. 267-272, pl., 2 diagrams, map.—Ecologic interpretation of the brackish *Unio* clays.

RUTH TODD



### ERRATA

In Article 54 of this Volume (CRESPIN: *Lepidocyclina* from Australia) the following corrections in the numbering of Plate 6 (opposite p. 21) should be made: 4 to be changed to 3; 5 to 4; 6 to 2; 7 to 1, and 8 to 5, in order to agree with the Explanation of Plate 6 at the bottom of page 21. On Plate 7 (same Article), opposite p. 32: 2 to be changed to 3; 3 to 4; and 4 to 2. Figs. 1, 5, and 6 unchanged

The Editor sincerely apologizes for this oversight. No plates will be accepted for publication henceforth unless they are properly composed and numbered by the author himself. In order to utilize fully the space of each collotype plate, figures should be arranged as closely together as possible. All plates and text figures submitted for publication **MUST BE READY** for the engraver.





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